VOL.
3
1952

OPERATIONAL RESEARCH QUARTERLY

Issued by the

Operational Research Club, London

VOL. 3 MARCH 1952.

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Hon. Sec. of the O.R. Club:
D. NEVILLE-JONES

Joint Editors:
MAX DAVIES

R. T. EDDISON
11, Park Lane, London, W.1. Grosvenor 4751

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VOL.
3
1952

OPERATIONAL RESEARCH QUARTERLY

VOL. 3 NO. 1. MARCH, 1952

Contents

Editorial Notes 1
Marshalling and Queueing 4
Abstracts 16
Notes from U.S.A. 20

VOL. 3 NO. 2. JUNE, 1952

Contents

A Rational Approach to Productivity Measurement . 21
Notes from the U.S.A. 23
Operational Research in Medicine—NORMAN T. J. BAILEY 24
Luggage Accomodation in Buses and Coaches . . 29
Abstracts 30
Reviews 34

VOL. 3 NO. 3. SEPTEMBER, 1952

Contents

Editorial Notes 37
Building Operations 39
O.R. in the Welfare State 50
Abstracts 51
The Operations Research Society of America . . . 56

VOL. 3 NO. 4. DECEMBER, 1952

Contents

An Indian View 57
O.R. Club Meetings.. 59
Road Behaviour of Vehicle Drivers—R. J. SMEED 60
O.R. in Electricity 68
Abstracts 69
Media Research Reports 72

VOL
3
199

VOL.
3
1952

OPERATIONAL RESEARCH QUARTERLY

VOL. 3 NO. 1. MARCH, 1952

Contents

Editorial Notes 1
Marshalling and Queueing 4
Abstracts 16
Notes from U.S.A. 20

EDITORIAL NOTES

Marshalling and Queueing

The greater part of this issue is given over to a report of the Operational Research Club's meeting on Marshalling and Queueing, which took place on March 17th.

A scientific newcomer to this field might ask three questions, answers to which were at least indicated at the meeting:

1. What do we mean by queueing, other than personally standing in line for scarce goods or service?
2. How far can scientific, particularly mathematical methods, be used to analyse and reduce delays inherent in queueing?
3. Are such results of practical use to industrialists and administrators? If so, how can they be presented to be most useful?

What is a Queue?

Briefly, queueing problems arise whenever delays occur or priorities must be arranged. The speakers at the meeting soon made it clear that their ideas of queueing widened the meaning of the term almost beyond the limits of its use in normal speech. The mathematical models and the solutions of the problems are, for example, the same whether the individuals or things are waiting to go through a "gate" or whether the "gate" is moving around to the waiting persons or objects. Applications described ranged from the reception and unloading of iron ore ships and aeroplanes to "help-yourself" teashops and the out-patients' departments of hospitals, and from the servicing of machines to designing the size of car parks.

Certain observational techniques are necessary for specifying the facts about how people or things queue up ("queue discipline"), how they arrive at the queue ("input"), and the way and the time taken

to serve them ("service mechanism"). Operational research methods thus have a threefold application in this connection: (a) in ascertaining the wide field of practical problems susceptible to similar treatment; (b) in the selection of appropriate solutions; (c) in obtaining the basic data to enable the problems to be specified.

The Scientific Approach.

The object of the scientific approach is usually to provide a method of prophesying how delays will be affected by varying conditions and so to make possible an economic evaluation of any efforts which might be directed towards reducing delays.

Fortunately, solutions and methods of analysis are now available which can be applied in a wide range of problems, and where mathematical solutions as such are not available, as K. D. TOCHER pointed out. specific problems can very probably be solved *ad hoc* by the use of the electrical delay storage or other high-speed calculating machines. (Mr. Tocher himself has worked out a programme of this sort, and has demonstrated that by feeding into the machine a supply of random numbers, problems mathematically intractable in the mathematical sense can be solved.)

As to the existing mathematical solutions, D. V. LINDLEY has been able to extend the work of D. G. KENDALL to cover a larger variety of "inputs." Mathematical solutions exist where there are uncorrelated inputs and service times (i.e., where the time of one arrival is not affected by the time of any other arrival, etc., and where the customer at the head of the queue is served first), while no great difficulty is encountered if the queue contains priority cases—they can be treated (mathematically) as though they formed a separate queue.

The general picture is illuminated by some of the practical examples given at the meeting. A problem of the arrangement and design of car parks at London Airport was described. Limitation of space makes it impossible to provide an unfailing service, but as the incidence of car traffic is "pretty well Poisson" and the service time at least approximately exponential, it has been possible to form a fair estimate of the number of cars per thousand which will have to be refused admittance to the central area. In the car parks themselves there is a straightforward queueing problem so that a lead can be given to the planning authorities on the number of entrance-gates required, and the design of the access roads. Thus potentially expensive (and exasperating) trial-and-error methods are eliminated. Another case where theory has been brought to bear on a practical problem is concerned with studies of unloading ore ships. The object is to establish what would be the cheapest and speediest service to meet a given demand, and it has been possible to determine the two components of the total cost (service provision and ships' time) and to relate these to traffic intensity. Because the total cost has a minimum at some value of traffic intensity, the optimum unloading capacity to handle a given quantity of ore can be

VOL.
3
1952

calculated. The optimum number of channels (berths) is also obtained.

Examples which had not so far proved amenable to mathematical theory were given by several speakers. One of these problems concerned a "two-way queue" in which objects arrive at a service point where the service depends also on another flow of objects as, for example, dirt arriving at a point for loading into tubs or wagons. When it was necessary to advise on the number of vehicles related to the size of the dirt hopper and the probability of the capacity of the hopper being exceeded, numerical methods had been used. Another problem was concerned with congestion on the taxiways at an airport due to aircraft moving between hangars, runways and parking spaces. Here each of many taxiways is a gate dependent upon input from other gates, forming what might be called "circular problems" where it is necessary to know the output of one queue before calculating the input to the next. However, empirical methods enabled recommendations on different traffic systems to be made.

The establishment of the proper queue discipline may often be the greatest difficulty where human queues are concerned as, for example, at a cafeteria restaurant. Here all the mathematical theory may be rendered void by a human tendency to follow the man in front instead of branching out boldly through an alternative gate which may be unoccupied and so able to provide service without delay.

To sum up, it can be said that the meeting offered a reasonably encouraging answer to the second question put by the scientific newcomer. Mathematical theory has got to grips with the subject and has mapped out the ground yet to be covered. Even where mathematics become intractable, there are good prospects of empirical solutions by means of electronic calculators.

Practical Application.

What precisely does this mean to the industrialist or administrator who asks how much space, staff or equipment he needs to keep delays to an economic minimum?

The most important point that emerges is that it can now be shown very often that a small change may make a very big difference to costs and delays. Queueing is a thing which very quickly gets out of control. If ten persons arrive every hour (at random intervals) in a shop where the assistant can on the average serve exactly ten persons per hour, a queue will soon be established, after which everyone arriving in the shop will have to wait. But if the input is reduced to eight persons per hour, then only three in every five will have to wait at all. Many queueing situations are balanced near this precarious position, with resulting expenditure of cash and nervous energy. In many cases the effect of any specific change can be accurately calculated on the basis of the existing situation.

Can this field of usefulness be extended? The prospects appear to be reasonably good, particularly with the extending use of computing machine techniques. For example, successful work has

been done at the Massachusetts Institute of Technology on arrivals scheduled as regular but arriving irregularly—the so-called "correlated" arrivals—which have hitherto defied analysis.

Another immediate extension of the field of usefulness of this work lies open. This is in its presentation to executives in a usable form. Fortunately, this sort of work lends itself to graphical presentation. The work at the Massachusetts Institute of Technology just referred to is presented as useful curves, and valuable work by BERKELEY (of the G.P.O.) has presented what have been called "the hideous formulæ" of other workers in eminently usable forms. It is similarly desirable, surely, to present the fundamental conceptions of the work in as simple and lucid a form as possible. The question was raised, for example, by the Chairman of the Operational Research Club meeting, whether it would be simpler to express service time not in terms of time, but in terms of its capacity or throughput.

Vis-à-vis the executive, the scientist has a two-fold aim: (1) he wishes to convey as unambiguously as possible to those who have decisions to make, the precise circumstances in which mathematical calculation can help them; (2) within these limits he wishes to offer his evidence to the executive in as straightforward a manner as he can.

Efforts under both heads are necessary and valuable in marshalling and queueing. Not the least encouraging feature of the recent meeting was the evidence it presented that they are being made.

MARSHALLING AND QUEUEING

Report of a Meeting of the Operational Research Club on March 17th, 1952

THE CHAIRMAN (Sir Charles Goodeve, F.R.S.) said that all studies of queueing related the queue to a "gate." Generally the persons or objects forming the queue arrived at the gate, but sometimes it was the gate itself which moved, as with service in a restaurant where the customers awaited the arrival of the gate in the shape of a waitress, or with machines in a works which awaited the arrival of a tool necessary for repairing or adjusting the machine. Thus, in any study of queueing, the type and frequency of incidence of the "input" needed to be visualised; at the "gate" the service time had to be considered, and this was related to the "capacity," which could be described as the reciprocal of service time.

Marshalling was the organisation of the input or the gate or gates. While queueing was a natural process, marshalling was the attempt to "do something about it."

Mathematical Theory

D. V. LINDLEY, of Cambridge University, speaking on "The Mathematical Theory of Marshalling and Queueing," said that queueing occurred when demands for service were greater than the availability of service, and it became necessary to postpone the demands by a system of queueing or marshalling. Queueing,

however, was essentially a temporary phenomenon, as otherwise the queue would grow indefinitely in size. It was thus one of the first problems in any queueing situation to determine when the demand would outstrip the service mechanism; if this did not happen so that the queue was continually returning to zero size, then the situation was said to be in equilibrium, or, in statistical terminology, the process is stationary. When the demand equalled the service capabilities the situation became very delicately balanced; a slight reduction in demand yielded a sensible queueing system in equilibrium, a slight increase resulted in an ever-lengthening queue.

Mr. Lindley then described four other technical terms, due to D. G. Kendall.

Input: The way in which the "customers" arrived at the point of service.

Queue-discipline: The manner in which they queued up for service.

Service-mechanism: The mode of service.

Output: The departing customers' method of leaving the system.

Input.

Until recently the mathematical theory of queues had been confined to the case of random arrivals. The input was random whenever the chance or probability that a customer would arrive at any instant of time was the same for all instants past, present and future and also was unaffected by any past or future arrivals. "It follows from these two assumptions," said Mr. Lindley, "that the probability that the interval between any two successive customers' arrivals will be exactly t is proportional to $\lambda_e - \lambda^t$ where λ is a constant. Thus the larger the interval, the less likely it is. The average interval is λ^{-1} so that λ is the average number of customers in unit time. The distribution $\lambda_e - \lambda^t$, is called the negative exponential distribution, or χ^2 distribution with two degrees of freedom. It follows from the second of these assumptions that the successive intervals are independent, so that, for example, a long period without a customer arriving does *not* imply that a lot of customers will arrive in the next period "to make up." A consequence of a random input is that the probability that exactly r customers will arrive in an interval of length T is $e^{-\lambda T}(\lambda_T)^r/_r!$. For fixed T this is a Poisson distribution and so the random input is often called a "Poisson input." D. G. Kendall uses the term, regenerative input.

Other inputs which commonly occur are those where the intervals between the arrivals of successive customers are independent with identical probability distributions, but this distribution is arbitrary. Thus the cases of random arrivals and regular arrivals are special cases. I shall refer to this as a "general independent input." Another interesting and important case is exemplified by the regular arrival case where the customers are not punctual but arrive early or late. If we assume that the unpunctualities of the customer are independent, then a moment's thought will show that the intervals

between arrivals are not independent. If customer r is late, so that the interval $(r-1, r)$ is longer than average, the interval $(r, r+1)$ will be shorter than average. (The intervals form a moving average process of the second order.) The successive intervals are said to be correlated, and I shall refer to it as a "correlated input," and use this term to cover more general types of correlation."

Queue Discipline.

Usually the customers formed a queue in the order in time in which they arrived. The case of V.I.P.s going to the head of the queue was usually dealt with by imagining two separate queues, one for V.I.P.s, and one for ordinary customers. An example of this sort was when an operator was attending to a number of machines liable to two kinds of failure. If one type was more serious than the other, then machines developing this type of failure played the role of V.I.P.s.

Service Mechanism.

Most of the work done in the theory of queues dealt with "one-at-a-time" mechanism. This could take several forms. The most usual situation was where the server attended to the customers one at a time, serving always the person at the head of the queue either as soon as he had finished with the previous customer, or as soon as he was available from other duties. If there were two queues he might attend to one until it was exhausted, as when it contained V.I.P.s, before dealing with the next, or he might select from the two queues according to some other rule. Another possibility was that the server might select a customer from the queue at random, each customer being equally likely to be selected. This was the method in certain telephone exchanges. There were also queueing problems where the service removes all or part of the queue in one operation, as with bus queues, but these were not considered by the speaker.

More variation was possible with more than one server. The simplest type was where the customer could go to any server who was free. There was also the "rotation mechanism" where with N servers the customers were bound to rotate the number of the server that they could use with a period of N. This situation was the same as N independent queues each with a single server, though the input to each separate queue was different from the input to the whole queue.

Service time ("holding times" in telephone work) had also to be specified. The usual assumption was that the service times of customers were independent of each other and other features of the queue, such as its size, or the waiting time of the customer at the head of the queue, and also the distribution was the same for each customer. The service-time and input distributions were closely connected.

VOL.
3
1952

Output.

Output was determined by the other factors, and was sometimes important because it became the input to another queue or even to the same queue again. Save for exceptional circumstances the output was "correlated" in the way described for input, and this correlation was of a type difficult to handle.

Methods of Solution.

In considering methods of solution two things were of particular interest, the size of the queue and the waiting time of the customer. The more randomness there was in the problem the easier it was to handle. Work by Erlang had made it possible to calculate distributions of queue-size and waiting times where the input was random and the service time was random, i.e., independent service with a negative exponential distribution, and the customer at the head was attended to first. Pollaczek had extended this work to a random input with general independent service, and Kendall had shown that the existence of the equilibrium position depended only on the mean interval between arrivals and the mean time of service: if the former was greater than the latter a unique equilibrium state existed, and conversely. The speaker had solved the problem for general independent inputs and services. The same necessary and sufficient condition for the existence of an equilibrium state persisted with a trivial modification, and in addition to the solution for this case the situation occurring at the commencement of the process was solved. The queue-size distribution could also be found from the waiting times, as had been pointed out by P. A. Wallington, a student of the speaker's. By these newer methods the case of regular arrivals had been studied for the first time. This showed that the customer's waiting time was often divided by a factor of four or more in these circumstances. Another interesting feature of this analysis was that the waiting-time distribution, though not the queue-size distribution, depended only on the distribution of the difference between the arrival intervals and service times and not on their individual distributions.

Mr. Lindley commented that Kendall had shown that where the customer's demand and the service possibilities exactly balanced, equilibrium did not exist and very large queues would occur. But a very slight reduction in demand could effect a very great change. "Suppose," he said, "that arrival rate drops from 1.0 to 0.8 customers per unit time, then in a typical case I have examined, the probability of not having to wait, increases from 0 to about 2/5, and the average waiting time decreases from infinity to 0.83 units; a very marked change. Many queueing situations seem to be balanced near this precarious position."

Where there was more than one server the situation was more complex and had only been considered in the case of a random input. Even here only two cases had been satisfactorily investigated without the rotation assumption, namely, when the service was random and

when it was fixed. When the rotation assumption was introduced the situation might be regarded as n distinct queues. If the input to the original queue was random, i.e., a χ^2 distribution with two degrees of freedom, then the inputs to the separate queues were independent with χ^2 distributions with 2n degrees of freedom, and the techniques developed by the speaker were available with general independent service.

Interdependent Input and Service Times.

Sometimes input and service times were not independent of each other. Both might be influenced by the size of the queue, and it was in these circumstances that the assumption of randomness was so useful. With random imports and service-times which vary with the queue-size the problem had been discussed by Jensen. Benson and Cox had used similar methods in discussing several variants of queues that arose when machines requiring attention could be fixed by only a single operator. By employing a device also used by Kendall and Erlang to make certain non-random situations random they had made it possible to analyse more general situations. For most situations the analysis is complex in manipulation but simple in principle.

Correlated input has not, the speaker thought, been examined, though he was working on the "unpunctual" case (mentioned under "Input" above) and had obtained an integral equation for the customers' waiting-time distribution. Whether or not it would be possible to solve this in any useful form it was not yet possible to say.

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Hospital Applications

BRIGADIER J. D. WELCH, of the Nuffield Trust, spoke on "Applications in Hospital Administration."

The extent of patients' waiting time at hospital out-patient departments was governed by two things:—

(a) the punctuality of patients and staff; and

(b) the consulting time per patient, relative to the rate at which they were told to attend.

Time studies and extensive field work had established that patients were on average early for their appointments, but at all the clinics studied waiting time was not less than half an hour, sometimes extending to 95 minutes. Doctors were less punctual, but this did not

VOL.
3
1952

account for anything like the whole of the patients' waiting time. If queueing was to be reduced, appointment systems must be organised to call forward patients more in accordance with the rate at which they could be cleared.

Work by N. Bailey at Cambridge on the many samples of consulting times collected showed that the length of consulting times followed a well-defined pattern which was satisfactorily fitted by a Pearson Type III distribution. It was then possible to "construct" 50 clinics, each of 25 patients, and to examine the consequence of the consultant starting his clinic with one, two, three, etc., patients present, and also the effect of varying the length of the appointment interval relative to the average consultation time. The average waiting time for patients and the corresponding total idle time for doctors followed a clearly defined curve, and on balance it seemed that a reasonably satisfactory optimum could be achieved by giving patients appointments separated by an interval equal to the average consultation time, and starting each clinic with two patients present. This would result in patients waiting on average nine minutes after their appointments and in consultants having an average idle period of less than six minutes per clinic allowing for patients arriving early.

There were other queueing problems in hospitals, which it was hoped to study in the future. Examples were the queueing of X-ray films for processing in the X-ray dark rooms, where there was a fixed service time and perhaps a partially controllable input. There was also the problem of the queueing of patients at the dispensary where there was probably a fixed service time for the standard prescriptions, but a variable service time for the non-standard prescriptions, and, possibly, a random input. These presented interesting contrasts with the out-patient departments with their controllable inputs but variable service times.

Civil Aviation

DR. G. E. BELL, of the Ministry of Civil Aviation, spoke on "Queueing Problems in Civil Aviation." This had provided, he said, a fruitful field for the study of problems of queueing, for almost everywhere the major aims were those of keeping some form of traffic moving quickly, and so designing facilities that the inevitable queues and consequent delays were acceptably small.

Air Traffic.

Air traffic control, concerned with aircraft in motion, had the task of delaying aircraft just sufficiently to provide adequate separation in the air according to standards in force. Aircraft, whether taking off or landing, presented themselves in a virtually random manner. Since separations were fixed by international rules there was for any given volume of traffic a built-in delay which could only be reduced by changing the form of the input distribution.

Once aircraft were in the air the problem became a multi-channel problem. The input was now no longer even approximately random, but had the form of a regular pattern with large errors. They had found it virtually impossible to find the actual distribution with any

accuracy, as the amount of data to be collected for an unbiassed sample was prohibitive. Further, such terms as "expected number of aircraft" and "average interval" varied from day to day and hour to hour, there was never statistical equilibrium and the theoretical problem accordingly became very involved and possibly meaningless. By applying to the predictions of the simple Poisson Theory empirical "form-factors" known to be about right, however, they had been able to forecast the capacity of runways six months ahead, and experience over some years had shown that the forecasts were neither unduly high or unduly low.

Vehicle Traffic.

The design of London Airport gave rise to a wide variety of problems concerning traffic flow in general and queueing in particular. A queueing problem that was not yet properly understood theoretically was presented by the vehicle traffic generated by aviation. By 1960 it was forecast that the Airport would give rise to some 1,500 vehicle movements in a peak hour, of which some 600 would have to cross the Bath Road across the east-bound stream of traffic, itself at a corresponding peak. A decision would soon have to be made whether traffic lights, a roundabout, or even a tunnel under the road would be best for control. There were somewhat similar problems connected with the arrival and despatch of vehicles at the main entrance to the Airport. Observation had shown that the average car or taxi took about two minutes to unload, and that the arrivals were, in fact, very nearly "Poisson." The number of unloading points required to handle this traffic expeditiously was in principle amenable to calculation, but account must be taken of the time consumed in manœuvring vehicles, which differed very considerably with different lay-outs.

Passengers.

In passing passengers through the ticket controls before going on to Customs and Immigration, it was necessary to have a number of parallel channels. While it was well known that a group of channels operated most efficiently if the channels were used in a fully co-operative manner, there were good operational reasons for limiting the inter-availability of channels. Passengers had a knack of straying, which led to loss of time, sometimes exceeding that gained by fully co-operative operation. Operators liked to handle their own customers, limiting the area in which they were found in order to reduce the number of handling-staff required. The problem of passenger-handling was thus not a simple study in the theory of queues, and must introduce various human and operational factors.

The Customs control came next for departing passengers, and Dr. Bell thought that operational research could give help in determining the number of officers and bench space required to give some prescribed level of service. Immigration control, however, which followed Customs, need not be very rapid as the passengers could not board the 'plane until the luggage was stowed, and this could not be begun until after Customs' examination.

VOL.
3
1952

Arrangements for arriving passengers were the mirror-image of those for departing ones, but the problem was a little easier because many passengers, particularly long-haul ones, welcomed a brief rest in the initial waiting room.

Car Park Design.

Another problem was a "lost traffic" problem in connection with car parking. They could not hope to provide an unfailing parking service when the Airport was completed. The incidence of car traffic was "pretty well Poisson," the service time at least approximately exponential, so that it was possible to form a fair estimate of the number of cars per thousand which would have to be refused admittance to the central area. In the car parks themselves there was a straightforward queueing problem so that a lead could be given to the number of entrance gates required, and the design of the access roads.

Unsolved Problems

K. D. TOCHER spoke on "Some Unsolved Problems." He described an airport problem, on which he had worked for Dr. Bell while at the N.P.L., which contained a wide variety of mathematically insoluble queueing problems.

This problem was to give an account of the congestion on the taxiways at an airport due to the aircraft moving between hangars, runways and parking spaces. Hold-ups at the numerous intersections formed a series of interconnected queues.

The first task was to define and measure congestion. A suitable measure, from the point of view of the airport authorities, was the average number of aircraft held up at any instant. However, an individual passenger was far more concerned with his experience on his journey across the taxiway system, and, from this point of view, a more suitable measure was the mean number of hold-ups to an individual aircraft on a typical journey.

Mr. Tocher showed a schematic diagram of London Airport which had been used in his studies. He explained how the traffic flow had to be regulated by one-way traffic conditions and by rules fixing the route of an aircraft between any two points on the Airport. The practical problem was to determine the set of rules which minimised the congestion.

The limited parking space available involved that some aircraft were unable to park at the allotted place and so were forced to use others. This altered the density and distribution in time of aircraft on the different routes in a manner which presented the first problem. This corresponds in some respects to the "lost calls lost" case in telephone loss theory.

"The parking bays," said Mr. Tocher, "are grouped in sets approached by a common taxiway which has a limited aircraft capacity set by considerations of safety. This limitation produces a queueing problem with a multi-service gate, which the service time distribution takes outside the range of the soluble problems.

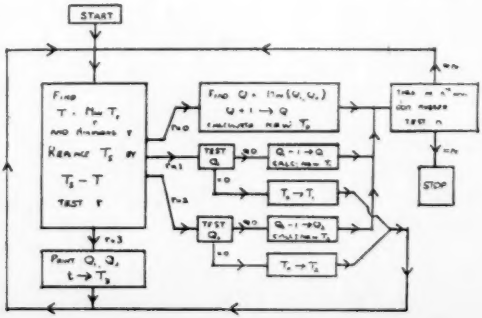
However, the main problem arises from the interconnection of the queues forming at the taxiway intersections. The output from each intersection divides along different links of the system, and are joined by the outputs of other intersections to form the inputs of other intersections.

This "circular problem" involves for an analytical solution the setting of and solution of a large set of integro-differential equations, which is quite beyond the means of present mathematical techniques. However, as Mr. Lindley has mentioned as a general rule, if sufficient assumptions of randomness are made, the set of equations can be reduced to a simple set of linear equations which determine the density of traffic through each gate, and which are themselves sufficient to determine the values of either suggested measure of congestion.

With these rather unrealistic assumptions, it is possible to grade the suggested systems of traffic organisation, and although the actual levels of congestion calculated are likely to be completely inaccurate, the relative values are, if telephone experience can be used as a guide, fairly reliable."

Mr. Tocher went on to remind the audience that Mr. Lindley had already listed quite a formidable list of mathematically insoluble problems. What was to be done about these problems? Many practical workers had conducted experimental investigations using models, but these were usually slower than the real queues, and took an enormous amount of time. To speed up these experimental methods special machines had been constructed. The most well-known examples were the "fictitious traffic" machines at The Hague and Dollis Hill, for telephone traffic work, the machine at the R.R.L. for traffic signal investigations, and the various electronic analogue machines for solving stockyard problems (which could be thought of as queues in reverse).

The speaker's main thesis was that since all these machines were primarily concerned with counting and calculation there was no need



Automatic computor programme for a two-gate queue problem.

VOL.
3
1952

to build a special purpose machine for each such problem, but that the new electronic automatic computing machines could be harnessed to solve all such problems by reducing them to an abstract system.

He illustrated this idea of a simple two-gate queue problem. "Suppose people arrive with any interval distribution we choose at two gates and join the shorter queue? Any desired service time distribution can be assumed. We require to study the size of the queues which develop in this situation."

Fig. 1 outlines the programme followed by an automatic computer in simulating this queue. At any instant, T_0 is the time of the next arrival to the queues. This can be calculated from the time of the last arrival time by adding a random number suitably transformed to represent a typical arrival interval. Similarly, T_1 and T_2 are the times of the next departures from the gates labelled 1 and 2 for convenience, while T_3 is a clock time at which the two sizes of the queues Q_1, Q_2 are to be recorded.

The programme determines which is the next event in the simulation by finding the least of T_0, T_1, T_2, T_3.

If this is T_0, then the minimum queue is found by comparing Q_1 and Q_2, and the least of these numbers increased by 1. T_0 is increased by a new arrival interval and the process repeated.

If the minimum is either T_1 or T_2, then if the queue is not empty (i.e., $Q \neq 0$) it is diminished by 1 and the time increased by a typical service time. If the queue is empty then the next arrival immediately enters the gate and so this arrival can be considered to coincide with a fictitious exit from the gate. T is set to the value T_0.

Finally, if T_3 is the least of the times, the queue sizes are printed and the clock interval added to T_3.

Using these methods we can either create the typical time intervals required from random numbers, or we may use records of the actual times involved in the real situation which is being explored.

The speaker did not feel that the use of these "Monte Carlo" methods should be regarded as anything but a stop-gap procedure, until a deterministic mathematical procedure could be suggested for the numerical evaluation of the probability distributions involved.

Discussion

In the course of the discussion which followed, D. G. KENDALL (Magdalen College, Oxford) remarked that some of the problems associated with systematic fluctuations in the intensity of the otherwise random input had been dealt with by Kolmogorov in *Rec. Math. Moscou (Matem. Sbornik)*, **38**, and by Palm in a long memoir published in *Ericsson Technics* (1943). He also pointed out that Pollaczek's work on the queues formed in front of N gates (with N greater than unity) was much more general than was commonly supposed. In fact, Pollaczek's paper in *Math. Zeit.*, **38**, appeared to contain a complete solution for the problem of N gates, a random input and a general service-time, the rule of queue-discipline being the natural one of "first come, first served," and not the cyclic one referred to by Mr. Lindley.

D. G. Kendall writes:

"Pollaczeck's paper (Math. Zeit. **38***) makes very difficult reading, and I understand that M. Pollaczeck has recently simplified some of the analysis. I am sure he would be happy to correspond with any member of the Club who is seriously interested."*

M. Pollaczeck's address, and those of two other French queue-theorists, may be obtained from the editors.

C. GORDON (Edinburgh) wanted to know if Brigadier Welch, in using the term "optimum," had referred to "an optimum of judgment." Was there a sufficient margin of safety to avoid enraging consultants when a patient was unpunctual or failed to arrive?

BRIGADIER WELCH replied that the object of the work was simply to give to consultants evidence of the effect on patients' and consultants' waiting time of various arrangements. The decision would lie with the medical authorities.

N. BAILEY (Cambridge Univ.) said that the fact that patients were early would "take up all the slack" and would provide an adequate safety margin.

T. E. EASTERFIELD (D.S.I.R) said that where economies were being sought at a risk of "finding oneself occasionally very short," study of sampling variations would also be important.

N. BAILEY replied that this was being done.

D. OWEN (B.I.S.R.A.) described studies of the economics of discharging ore from ships, the objective being, as with other queueing studies, to find the cheapest way of avoiding delay, and to decide how much should be spent for this purpose.

In the case of ore unloading it had been necessary to determine the optimum quality (speed) of service to meet a given demand. The total cost was the sum of the cost of providing service (operating cranes, etc.) and the value of the customers' (i.e., the ships') time. The mean values of these could each be related to the traffic intensity, and, since when this increased the service cost fell and ships' time cost rose, the total cost had a minimum at some value of traffic intensity, from which one could calculate the optimum unloading capacity to handle a given quantity of ore. The optimum number of channels (berths) was also obtained.

In general, the problem was whether it was better to provide (a) faster service at a single channel, so reducing both the customers' service-times, and their delays, or (b) more channels with similar service, which reduced only delays. Generally the former was preferable on economic grounds, but there was a point beyond which it would be uneconomic to improve the service.

B. H. P. RIVETT (National Coal Board) described three particular problems in which his organisation was interested. The first was concerned with a "two-way queue" where objects arrived at a service point where the service depended on these and another flow of objects. An example was dirt arriving at a service point to be loaded into tubs or wagons. The questions of the number of vehicles related

VOL.
3
1952

to the size of the dirt hopper and the probability of the capacity of the hopper being exceeded had to be answered, and for these calculations both inputs had to be known. They had been reduced to solving the problem numerically, and he thought that this might be a case where the computing machine could be used as suggested by Mr. Tocher.

The second problem was concerned with underground telephone systems, which could be of vital importance. Studies had been made of delays in calls from one extension to another *via* the exchange. Component times could be analysed, but the problem of service time was troublesome. A bi-modal distribution of times for extensions to answer the telephone was found.

The third problem was where a service time was dependent on the time since the queue was last at zero. An example was where a haulage hand transfers tubs from one type of haulage to another. In some cases there might be a tendency for tubs to pile up one behind another, waiting to be transferred, and the walk to successive tubs would get longer and longer until the queue was cleared, when the next tub would stop right forward and the walking time would be a minimum once again. In this case there would probably be a much more restrictive condition on the arrival time distribution.

W. K. CLARKE (J. Lyons & Co. Ltd.) said that queue studies in "help yourself" teashops had shown that rush hours input was remarkably consistent. Investigations of service speeds at various shops had shown that it tended to fall when spending power was higher and/or when there was a greater variety of choice. The length of the counter could be varied to affect service time. Five customers per minute could be serviced by a normal counter, but there was no point in speeding up service unless seating capacity was kept in balance. Customers spent an average of 20 minutes seated at lunch.

L. H. SAVIN, commenting on Brigadier Welch's paper, said that the length of the queue itself had an appreciable effect on the speed at which a doctor worked; a long queue might make a doctor hurry, or beyond a certain point might cause him to slow down in despair. Similarly, the effect of fatigue might be either to make a doctor "snappier" and faster or it might slow him down.

BRIGADIER WELCH and N. BAILEY agreed with both these points. Clinics should not, in general, exceed 2¼ hours without a break.

R. T. EDDISON (B.I.S.R.A.) referred to the possibility of using two (or more) channels or gates in series instead of in parallel. The customers would receive part of the service at the first gate and would then have to go on to the second gate for completion of the service. It could be shown that the delay arising from two gates in series would be greater than for two gates in parallel if it were assumed that the service time was constant and the first channel provided exactly half of the total service. If the first gate did not provide as much as half

the service, delays would arise at the second gate so that the total delays with gates in series would become greater. There might, however, be technical reasons for providing a different grade of service at the second gate, and, in that case, the arrangement of two gates in series might be advantageous in spite of its inherent tendency to involve greater delays. The proper assessment of this situation would require an estimate of the delays at the second gate, the input to which would be the same as the output from the first. He was sorry to hear from Mr. Lindley that no general solution was known to this problem.

M. H. JOHNSON (Ministry of Civil Aviation) drew attention to recently published work in the U.S.A. At the Massachusetts Institute of Technology solutions had been found to problems where arrivals were correlated—scheduled at equal intervals but arriving irregularly. The I.B.M. machine had been used. Three types of distribution of errors had been used, rectangular, triangular and parabolic. Results had been published in a usable form as graphs.

Mr. Johnson also drew attention to work in this country by Crommelin and Berkeley of the G.P.O. Crommelin had covered a field similar to but more restricted than Pollaczeck, and like him had "finished with some hideous formulæ." Berkeley, however, had constructed usable graphs from some of these, and had published them in the *Post Office Electrical Engineering Journal.*

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ABSTRACTS

Productivity Standards—Warehousing.

S. STOKES TOMLIN (Shell Oil Company).
Advanced Management; March, 1951, **16** (3), 19-22.

Distribution costs form about half the retail price of consumer goods. Yet many business men pay little attention to distribution. In the author's opinion the next fifty years will become the age of scientific and mass distribution.

Faced with the need to cut costs, the Shell Oil Company decided to see what could be done on distribution. A Distribution Study Committee was set up, its first task not to cut costs but to find out what they were. This committee limited its study in the first place to one large representative area. The study of costs from refinery to depot was straightforward; from arrival at depot to consumer was not. To study the latter all the depot operations were split into five main categories and a job analysis form was set up for each man

VOL.
3
1952

in each category. For some categories sheets were very detailed.

Possible resistance to filling in these forms was overcome by giving at the start a full explanation of the need for the investigation. Excellent co-operation was, in fact, obtained. The forms were left with the employees for a month. At the same time, the committee made a detailed analysis of the paper-work done in the depot and broad cost surveys in the plant were made.

Many valuable conclusions were drawn from this study, which led to specific remedies being introduced. A few of these are listed. Finally reference is made to the need to keep abreast of changes in distribution costs. This should be done by occasional spot checks at various plants rather than by cumbersome, continuous distribution cost studies.

Operations Analysis and the Theory of Games: An Advertising Example.

LEONARD GILLMAN (Massachusetts Inst. of Technology).

J. Amer. Statist. Ass.; Dec., 1950, **45** (252), 541-545.

The theory of games is applied to an advertising competition. A simplified, hypothetical model is set up in which two contestants are trying to secure an order from a potential customer. The only weapon they can use is advertising. One of the contestants is near bankruptcy and must, therefore, obtain the order before a certain date, if at all. The other is doing good business and would be satisfied if his advertising achieves no more than preventing the first from getting the order in time. How should each one spend his money on advertising?

Functions of susceptibility and resistance to advertising are used in a mathematical model to determine the strategy and spending rates of the two participants during the campaign.

Fuel Economy—The Home Fires.

J. C. WESTON and W. F. B. SHAW.

Research; October, 1951, **4** (10), 455-462.

Experiments on the heating of houses are reviewed which "have already provided a large body of data on which executive decisions can be based."

The paper is in two parts, the first dealing with appliance research which is mostly laboratory work. The second part deals with the use made of experimental houses, and this can fairly be called operational research. One group of eight houses was built in which the methods of heating installed were similar, but the methods of construction of the houses gave very different insulating properties. Tests of temperature and fuel consumption were first made in the empty houses and then, over a period of four years, in the houses occupied by tenants living their normal lives, as far as possible undisturbed by the experiment in progress. From these experiments it was possible not merely to derive an economic balance between the cost of better insulation and the resulting saving of fuel, but also to study the reactions of the occupiers to the better insulation. Thus, in general, it was concluded that improved insulation could be justified by possible fuel economy but that it was difficult to persuade the tenants that the increased rent could be balanced by fuel saving or greater economy

Other experiments have been made with houses of similar construction, but with a wide range of heating appliances. In this case the tenants were moved round from house to house at yearly intervals

in order to avoid experimental confounding of particular tenants with particular appliances.

The Verification and Scoring of Weather Forecasts.

IRVING I. GRINGORTEN (Air Force Cambridge Research Center).
J. Amer. Statist. Ass.; Sept., 1951; **46** 255, 279-296.

This paper presents a particular application of principles and methods applicable to periodical forecasts of many kinds.

The key points of previous work are reviewed and accepted except that a clear distinction must be made between the utility of a forecast and the skill of the forecaster.

The utility of a forecast should be judged by the operational requirements since the forecast becomes the working assumption. In some cases no more than climatic frequency of a persistence forecast can be given. A scoring system must therefor be an index of the value of the forecast for operational needs. When a forecaster is asked to forecast a single event he, in effect, is making the operational decision because he cannot predict the weather precisely, and the forecast must be governed by the economics of the operation.

Skill is defined as the forecaster's ability to analyse and classify antecedent weather so that, within one class, the probability of a subsequent event is increased above, or decreased below, the relative frequency of that event in all weather situations.

Three forms of forecasts are considered: (1) Selection of a single event from (n + 1) mutually exclusive events with partial credit for a choice depending on the nearness to the observed event; (2) Selection of one or more events as alternatives with greater credit on verification for fewer alternatives; and (3) Dichotomous grouping of (n + 1) events and selection of one group. Scoring formulas for utility and skill are developed for all three forms of forecast.

In conclusion, forecasters should make separate forecasts for a skill rating independent of their operational duties, and these may be inconsistent, but have common features of which one is the ability to classify antecedent weather with a probability of the forecasted weather greater than the probability derived from climatic frequency.

Operational Research and Control.

D. R. G. DAVIES (Richard, Thomas & Baldwins Ltd.).
R.T.B. Quarterly, Sept., 1951, **13**, 25-29.

In the steel industry an important contribution to higher productivity in U.S.A. is made by the technical teams working with management in the pursuit of a fuller understanding of the inter-relations of process variables with quality and output, and with a determination to state these relationships in quantitative expressions capable of being translated into action. The name "Department of Quality Control and Steel Conservation" is eloquent of an attitude of mind prevailing in most American plants.

Two examples are given of the use of statistical techniques; first, the use of quality control charts for general works control and in particular for the avoidance of waste. Secondly, correlation analysis is used to show the relationship between various operating conditions in the process of steel melting.

VOL.
3
1952

Book Review

Rubber Technology.

R. C. W. Moakes and W. C. Wake (Editors).

Butterworth, London, 1951. (xiv + 199 *pp.,* 25s.)

The book comprises a series of lectures dealing with recent developments in a number of different fields of rubber technology rather than with the technology in general. The chapters are: (1) Technology in 1951 and After, by J. R. Scott; (2) Latex: From the Tree to the Finished Article, by W. J. S. Naunton; (3) Recent Developments in Compounding, by R. C. W. Moakes; (4) The Significance of New Ageing Tests, by J. Mann; (5) Developments in Testing Instruments and Test Methods, by A. L. Soden; (6) Resources of the Woven Fabric Designer, by W. E. Morton; (7) Statistical Techniques in Rubber Technology, by W. C. Wake.

In the last chapter the application of the statistical technique of rank correlation in operational research is discussed and exemplified. Following the introductory remarks there is given a short definition of operational research with two examples in outline drawn from the textile industry and road research to show the typical fields and general methods of application. Two experiments with products of the rubber industry are used to illustrate the detailed methodology, the first being concerned with the judgment of the " handle " of rubber proofing and the second with the wear caused by the belt on double-texture waterproofs. A section is then devoted to suggesting how operational research could be applied to assessing productivity in the rubber industry. In the final section the arithmetical procedures used in the correlation analysis are described, together with some account of the analysis of association.

In presenting this article the author has performed a useful service in calling the attention of rubber technologists to some of the techniques which exist for giving numerical scores to data ranked on a subjective basis in such a way that they may be analysed objectively. The methods of analysis used are those described in Professor M. G. Kendall's most valuable book " Rank Correlation Methods," to which Mr. Wake makes full acknowledgment.

In rubber technology there are many effects which are difficult to express quantitatively as, for example, processability and degree of cracking, and one could wish that the author had devoted more of the space to showing and explaining at greater length how the statistical techniques he rightly advocates could be generally applied to improve objectivity of judgment in such cases. Instead, he has attempted to show how the statistical methods fit into a framework of operational research. From the chapter heading the reader expects to learn something of statistical methods, which indeed he does, for the examples in rubber technology are concerned with the step-by-step procedure adopted in planning and analysing two industrial experiments. However, since the main emphasis is on the statistical

method the reader is left in some doubt as to how the experiments differ essentially from any other industrial experiment planned on a statistical basis. He may be inclined to believe that, after all, operational research is no more than the application of statistics to industrial problems. Statistical methods have played an important part in operational research, of course, but they are not the whole story, and it is felt that the detailed examples fail to demonstrate convincingly the other essential attributes of operational research.

With two statements the reviewer finds himself in disagreement. The first occurs on *p.* 166: "The probability of scoring a success by chance is 1/6. Each judge has 18 tries, so that he is bound to score at least one success. . . ." Much, however, depends on the definition of "bound" by which the author may not mean "mathematically certain." The second, made twice in more or less the same words on *p.* 159 and *p.* 178, where the author states most emphatically that operational research is not the appropriate technique to use for "trouble-shooting" which he defines as finding the cause of sporadic faults. But surely statistical quality control, a notable example of operational research, has proved itself to be of the greatest value in trouble-shooting?

Into a compass of 29 pages have been compressed ideas which could be usefully expanded to book length, and for this reason may not receive the attention they deserve.

B.J.A.M.

Notes from the U.S.A.

We have received Vol. 1, No. 1 (O.R. Supplement No. 1), of a four-page folder entitled *Case Reports*, dated December, 1951. It is issued by the Engineering Administration Department of the Case Institute of Technology, Cleveland, Ohio, U.S.A., and contains news of O.R. developments there and elsewhere in the U.S.A. Publication "at intervals" is planned, and it is stated that copies will be gladly forwarded to interested persons. Members of the O.R. Club have been dealt with *en bloc* and need make no further application.

The same department of the Case Institute proposes to run a short course in operations research from June 16th to June 27th next. It is planned to devote each morning of the course to the explanation of an aspect of operational research, the practical applications of which will be discussed during the afternoon. The topics proposed for this treatment are: methods of measuring the effectiveness of operations; probability theory; probability models applied respectively to communication, inventory, maintenance (life and death patterns), sales policy and production scheduling; modern sampling techniques; measuring "intangibles."

VOL.
3
1952

OPERATIONAL RESEARCH QUARTERLY

VOL. 3 NO. 2. JUNE, 1952

Contents

A Rational Approach to Productivity Measurement . 21
Notes from the U.S.A. 23
Operational Research in Medicine—NORMAN T. J. BAILEY 24
Luggage Accomodation in Buses and Coaches . . 29
Abstracts 30
Reviews 34

EDITORIAL NOTES

A RATIONAL APPROACH TO PRODUCTIVITY MEASUREMENT

THE Operational Research Club showed its interest in productivity measurement by making that the subject of the open meeting for 1951, under the Chairmanship of Sir Henry Tizard. In its March issue of that year this Quarterly accepted the definition of productivity measurement as "the relationship of output of goods or services to the several elements of input, which can be classified as labour, capital, land and organisation," and in answering the three questions, what? why? and who? we expressed the hope that the key question "how?" would be answered in the near future.

Since that time it appears that productivity can be said to have emerged from being an object of propaganda, to take its place as a tool of management. The improved quantitative basis on which the subject stands can be said to have contributed to this transition, and a recent publication demonstrates this while taking the process a step further. This is the report of the Iron and Steel Productivity Team which visited the U.S.A. in 1951.

In addition to giving important technical details of American and British iron and steel practice, the authors of the report lay down precise rules for defining and measuring productivity and related quantities in the iron- and steel-making processes. While these are of direct use only to that industry, they are applicable as a pattern to a wide range of industries.

The objective was to find quantities which could, from available statistics, be determined with an accuracy such that changes of these quantities over a period of time or differences between them under various sets of conditions, would have sufficient significance to enable conclusions to be drawn and reliable decisions to be made. It was also desirable that the quantities should be readily convertible to costs so that the economic consequences of decisions could be

assessed. One of the important conclusions of the report is that trends in productivity or related quantities are much more easily analysed or extrapolated than trends in costs, as the latter contains the fluctuating element of price rates.

Productivity is a ratio, being the output of a given product divided by the amount of any one of the resources which are together necessary to achieve that output. The reciprocal of this is the "resources consumption rate," there being in both these terms separate indices for each of the resources. (The authors point with surprise to the frequent use of the term "productivity" to mean the reciprocal of this quantity.)

In the making of iron and ingot steel for the bulk-steel industry the output can be simply measured in tons. The variations in quality are not sufficient to introduce serious error, and the by-products represent a secondary part of the output. In rolling mills, however, output cannot be measured accurately owing to the great variations in size and shape of product.

The more important resources making up the input can be classed under four headings: (a) raw materials, (b) fuel, (c) operative time and (d) plant time. The authors chose the "plant productivity" (or output per unit of plant, such as a blast or open hearth furnace) as the basic quantity because the statistics related thereto are the more reliable and because this quantity can be analysed into the important factors which affect output. Plant productivity can be converted to labour productivity by dividing by the manning rate, although the published statistics about manning are not very reliable.

The input of plant time, however, requires careful examination, and is here approached by first defining the "effective capacity" of a works as the expected output over a period of time, given normal operating conditions of raw materials, fuel, maintenance, etc. This is less than the theoretical capacity, the sum of all the individual furnace capacities, because of the necessity of routine down-time for repairs. The ratio of the effective to the theoretical capacity is the "availability" of the units of plant. The actual output may temporarily exceed the effective capacity, but generally averages somewhat less, depending on the actual "utilisation." These three terms, effective capacity, availability and utilisation, are of great value, the first in prediction, and the second and third in assessment of maintenance and of unplanned stoppages or slow-downs respectively.

Associated with the effective capacity is an estimated number of furnace weeks of operation in a year. This is taken as the input of plant time, which, when divided into the tonnage of output, gives the "furnace productivity." Statistical analysis of productivities of furnaces taken over a wide range show the effects of size, of driving-rate and of qualities of raw materials. In this way it is possible to put many common generalisations to quantitative tests.

The quantity "resources consumption rate" is preferred when dealing with the other resources (materials, fuel and operative time). One reason, as already given by Tippett, is that inside any one category, consumption rates can be added. For example, the "direct

VOL.
3
1952

labour-hours per ton" can be added to the indirect, the maintenance, the supervisory, etc., hours to derive a "gross man-hours per ton." A more important advantage arises from the fact that consumption rates, when multiplied by cost rates (such as wage rates or costs per ton of raw material) give directly the cost components, the sum of all such components giving the total costs. In this way the cost of making steel in 1950 has been broken down into stages of process and components to show the effect of consumption rates on costs.

This quantitative treatment permeates much of the report, but there are chapters which must of necessity be treated qualitatively or descriptively. If followed up by regular analyses, more valuable information will be obtained. Its extension to other parts of the steel industry and to other industries is much required.

MR. LOUIS MOSS, director of the Social Survey, has been elected president of the Market Research Society.

NOTES FROM THE U.S.A.

THE course on Operations Research, announced in our last issue, to be planned by the Case Institute of Technology for 16th June to 27th July, duly took place. R. T. EDDISON, joint editor of this Quarterly, lectured to the course, which we hope to report in our next issue.

Case Reports. **1** (2) (O.R. Supplement No. 2) carries a note on "Science and Policy," which includes these sentences:

> "For operations research the research is not completed until *conclusions have been integrated into a policy set-up.* Many are finding that the so-called scientific aspect of operations research is only a small part of the whole problem . . . The tough part of the research is showing how an agency or a business or an industry can work the recommendations into its policy . . . Which comes first, science or policy, is a chicken-and-egg kind of question. For operations research, science and policy are not separable. Operations research is not an answer-book technique which industry can take or leave as it likes. *How* industry uses operations research is the most critical problem operations research faces today."

We welcome the formation of an Operations Research Society in the U.S.A. A preliminary meeting was held at Columbia University, New York, at the end of May, under the chairmanship of Professor PHILIP M. MORSE, of the Massachusetts Institute of Technology. We are also pleased to welcome Professor Morse as an editorial adviser to *The Quarterly.*

OPERATIONAL RESEARCH IN MEDICINE

by

NORMAN T. J. BAILEY

A GREAT deal of medical research is directly aimed at improving some specific aspect of curative or preventive medicine such as the development of a more powerful chemotherapeutic agent, a new serum giving greater protection against some infectious disease, a new surgical technique, more accurate and reliable methods of diagnosis, and so on. The activities involved may range all the way from biochemical or physiological laboratory experiments, or an abstract mathematical analysis of the behaviour of an epidemic, to controlled clinical trials in hospital wards and out-patient departments, or a complex ecological study of the whole environmental situation associated with a particular disease. The research workers concerned may either be relatively isolated individuals working more or less independently of each other, or they may be organised into teams of investigators, including doctors, social workers, statisticians, and so on.

None of the pursuits broadly outlined in the previous paragraph qualifies as operational research in its own right, although it may be part of such a programme. Operational research in medicine is concerned with the organisation of existing clinical techniques and facilities so as to make them more widely available to patients in need; with the replanning of wards, clinics and practices so as to employ present resources to the greatest advantage; and with the general administration and planning of medical services. All the disciplines of scientific research in general and medical research in particular can be made to subserve these ends.

The initial stages of the transition from the investigation of narrowly circumscribed problems to the broader operational level are excellently illustrated by the recently published M.R.C. report: *The application of scientific methods to industrial and service medicine* (1951, H.M.S.O.). This report is essentially the proceedings of a conference held in March, 1950, the subject of which was comprehensively defined by Dr. Himsworth in his opening address "as the solution of the problems that are raised both for the individual and for the group by the organisation of human effort."

Operational research of any kind (and the medical field is no exception) usually entails a considerable amount of survey work, especially of the type commonly encountered in socio-medical investigations. In order to ensure that such surveys are adequately designed at the beginning and are efficiently analysed and reliably interpreted at the end, it is usually necessary to have competent statistical advice. At the same time there is much to be gained if the other investigators are at least acquainted with some of the statistical requirements, and are on their guard against the pitfalls associated

VOL.
3
1952

with sampling and realise the importance of proper controls, for example.

Field Surveys

Very wisely, therefore, the first group of papers read before the conference dealt with "Scientific method in field surveys." The discussion was opened by Professor Bradford Hill who spoke on the general principles. He gave some shrewd advice on the avoidance of various difficulties which beset those undertaking such surveys. Special points which he emphasised were the design of questionnaires, the importance of having representative samples, and the use of appropriate controls. Further papers then followed giving details of specific applications, including a survey of sickness incidence in the G.P.O., occupational factors in peptic ulcer, medical field surveys in industry and the services, and occupational and domiciliary factors in pulmonary tuberculosis. Special attention was paid to selecting records at random, using methods of double-checking the sources of information, trying to avoid missed cases and reducing lapse rates, etc. Although particular topics were under discussion, these papers may be read with profit by anyone undertaking this kind of work as they contain much valuable advice which is of general application.

Another section of the conference was devoted to the consideration of health hazards, especially fluorosis, berylliosis and pneumoconiosis; the physiological effects of heat and anatomical factors in machine design. It is obvious that in all such problems an *overt* case of disease requires the best clinical treatment available. On the other hand, the *prevention* of disease under conditions which are more or less predisposing is essentially a problem of the reorganisation or modification of the processes involved. Analysis of the general environmental conditions, particularly those under partial control such as temperature, humidity, dust level, and so on, is the first stage in finding out just what changes should be made to bring about the *ecological*, as opposed to the *clinical*, control of the disease in question.

Analogous studies on the improvement of human performance by laboratory analysis formed a third main division of the subjects discussed by the conference.

It should be said, however, that much of the work discussed in the papers read before the conference is really operational research by implication only, that is, the detailed reorganisation and planning in accordance with the suggestions arising from the investigations still remain to be elaborated. Nevertheless, the preliminary stages are clearly exhibited and well worth further study.

Hospital Organisation

A second recent publication, the *Report of the Nuffield Provincial Hospitals Trust for 1948-51*, illustrates the application *par excellence* of operational research to medicine. The Trust is primarily concerned to improve the medical care available to the patient. To this end it has sponsored various investigations directed at producing

a better integration and planning of existing facilities, covering the analysis of hospital and public health nursing, the functions and design of hospitals, uniform methods of hospital costing, the design of health centres, the organisation of general practices, and the co-ordination of medical care. Most of these projects have not yet been finally completed, but details of some of the work are already available in published form, and in any case the general review provided by the present Report is quite sufficient to show the kind of results that will emerge. Many of the topics treated are worth looking at a little more closely.

First, there is the analysis of hospital and public health nursing. This was prompted by the Ministry of Health's working party on the recruitment and training of nurses which produced a very important report in 1947. In the time at their disposal, the working party were unable to amass sufficient data adequately to determine what was the proper task of a nurse, and the Trust decided to undertake an extensive job-analysis of the problem. To this end "a complete analysis of the work-content of twenty-six wards in thirteen hospitals was undertaken," covering a variety of different specialties. The analysis of this material shows the various kinds of jobs performed, who did them and how long was spent on them; as well as giving particulars of the amount and kind of work carried out for individual patients. In this way a general picture has been compiled. The Trust comments that "when the findings of the job-analysis are issued it is hoped that they will be of assistance to the hospital world in general and the nursing service in particular, not least because a perfectionist approach is being avoided and proper account taken of the limitations imposed on the health service by lack of finance and labour." The parallel investigation of public health nursing has been obliged to pursue its enquiries by means of questionnaires. Nevertheless, it is considered that it will "provide the essential factual information, at present lacking, on which any reorganisation of local-authority work, or the redeployment of nurses, in the public health field will need to be based."

The second big investigation is the one concerned with the functions and design of hospitals. The team involved has employed the services of a physician, a nurse, a field-work organiser, an historian, an accountant, an architect, as well as being assisted and advised by experts well qualified in other fields. In particular, the investigation is guided by an expert panel of eminent advisers, covering medicine, physical science, nursing, administration, and so on. The enormous field of possible study has inevitably to be somewhat restricted, and the work actually carried out may be conveniently classified under the three main headings: the ward; the out-patient department; and the hospital case-load.

Let us consider the implications for ward-design first. In the strictly medical field, studies have been made on the incidence and control of cross-infection; the proportion of single rooms which ought to be provided on medical grounds in wards attached to different

specialities; and the consequences of a policy of early ambulation. The results obtained on the first of these topics seem rather vague, but, on the last two, definite conclusions have appeared in papers published in the *Lancet* by the medical member of the team. So far as single room accommodation is concerned the problem is one of balancing the conflicting requirements of medical care, economy and adequate nursing supervision. On purely medical criteria it has been shown that in fact quite a small proportion of single rooms should suffice—approximately a quarter and a fifth in medical and surgical wards respectively. The policy adopted in any particular ward with regard to early ambulation has important repercussions on the ideal design. For example, if there are more ambulant patients, and more lavatories, a larger day-space will be necessary. Another aspect of ward-design has involved time and motion studies of nurses at work. These studies have provided basic data on the distances walked by nurses, the kind of routes followed, and their frequencies. On such information depends the optimum siting of beds, anciliary rooms, etc. Architectural studies have also been pursued in close co-operation with the ward investigations just described. The director and architect of the team, Mr. Richard Llewelyn Davies, has experimented with various alternative ward designs with a view to incorporating as many as possible of the advantages demanded by the preliminary researches. The result has been a specific plan which is wide and compact, in contrast with the usual "corridor" design. It is to be used as a basis for experimental ward units which are being built at both Greenock and Belfast. When these are completed and actually working it will be possible to carry out further experiments in the organisation and planning of a ward as well as demonstrating whether in fact the general proposals and recommendations of the Team will run efficiently in practice.

Other studies are being made of out-patient departments at various hospitals. Again, the time and motion technique has been employed. This has led to two important advances. First, definite guidance is expected to be forthcoming on the best general design of the surroundings and siting of the equipment, the size and nature of the staff, the numbers of patients that can conveniently be dealt with, and so on. Secondly, proposals are being prepared as to the optimum design of appointment systems, based on the relation between consultation times and waiting times. This means that it should be possible to rationalise the flow of patients through a clinic, to reduce substantially the time they normally have to wait without wasting the consultant's time, and to reduce the amount of waiting-room accommodation usually required. [Some details of this work were discussed at the O.R. Club's meeting on March 17th, reported in the last issue of this Quarterly.—ED.]

The third main section of the hospital investigation is the study of case-load problems. In order that a hospital may efficiently fulfil its fundamental purpose of providing the hospital care required in the area it serves, a certain number of beds ought to be available in

each speciality. The precise optimum is often very uncertain, but an approximate solution of the problem can be obtained by observing what happens for specialities serving certain definite catchment areas. It is obviously possible, by relating discharge and admission rates, lengths of stay, size of waiting lists, etc., to estimate how many beds should be provided and to compare this with the actual number. This investigation is still in progress, but when its report is presented at the end of this year it is clear that the results will be of fundamental importance in making the best possible use of existing hospital facilities.

A third field of research is the subject of hospital costing. If the available resources, whether medical and nursing skill, clinical treatment, drugs, special facilities, building accommodation or financial grants to the hospital service, are to be fully utilised, then some standard method of comparing the cost of various services in different hospitals and at different times is absolutely essential. Standard methods of hospital costing have been worked out and have not only been used experimentally for various hospital groups but have also had special application to the work of the team investigating the functions and design of hospitals.

Health Centres

Another valuable sphere of activity is the work on the design of health-centres which is also sponsored by the Trust. In spite of the general economic set-back to the widespread development of such centres it may well be a positive advantage that it is at present possible to promote only a small number of carefully considered experimental units, some of which will be able to provide really efficient prototypes for large scale adoption in the future. There is the Darbishire House scheme (sponsored jointly with the Rockefeller Foundation), which is attached to the University of Manchester medical school and which will be developed as a teaching health-centre designed eventually to introduce medical undergraduates to the kind of work occurring in general practice. A diagnostic health-centre, including maternity beds and general practitioner beds, is to be built to serve the new town at Corby, and a simple type of centre is planned for part of the new town of Harlow. While these projects may take some years to produce concrete results their ultimate value can scarcely be over-emphasised.

Other studies, which are really complementary to the foregoing, include a survey of group practices in order to find out what advantages are already being reaped from this kind of unofficial group organisation; and some preliminary surveys in the East Anglian Region of the whole field of medical care and specialist services.

In a report of this type one could not expect all these topics to be illustrated in detail. Nevertheless, the material presented gives some highly stimulating and fascinating glimpses of work which is of fundamental practical importance to the whole community.

It is abundantly clear that there are vast opportunities for using the methods of operational research in medicine. No matter how

VOL.
3
1952

efficient the basic medical care and treatment, there will always be the problem of ensuring that it is made as widely available as possible. Indeed in many under-developed countries the most urgent need is for the dissemination of relatively simple hygienic principles: the main problem is one of organisation and planning rather than "pure" medical research.

Social medicine, which is essentially concerned with the unitive study of Man, in both health and disease, in relation to his environment (as opposed to the classical type of medicine where the main object is to treat and cure the individual), will only be successful in so far as it can make definite proposals about the control of environmental conditions, the modification of the individual's patterns of behaviour, and the reorganisation of the curative and preventive medical services available: this is precisely the task of operational research in medicine.

LUGGAGE ACCOMMODATION IN BUSES AND COACHES

The following note on an interesting investigation is made available through the courtesy of London Transport Executive.

THE vast majority of London Transport bus passengers travel light, but a few carry luggage and parcels of greater bulk than the usual small case or handbag, and some provision is made for them in the form of luggage racks or of a space beneath the staircase. The space available is limited by the over-riding necessity for maximum seating capacity, but an investigation has been made into the nature, size and amount of luggage carried by passengers to find out whether the existing vehicles have sufficient room for luggage and whether more generous facilities could be justified in future designs.

Two surveys were made, in November, 1950, and in August, 1951, the latter to give a measure of the peak holiday traffic in luggage. Observations were made by uniformed ticket inspectors while engaged in their normal duties, and it was possible to plan the surveys to cover the whole of the various fleets at each time.

The survey was, and had to be, of the extent to which present facilities are used; it is possible that passengers would take more luggage with them if they could be assured of sufficient accommodation for it, but this latent demand for luggage space is considered to be small, for it was found that few buses carried more than one or two pieces of luggage. It follows that it is usually possible to find room somewhere on the vehicle for a further suitcase or two. Moreover, complaints of inadequate luggage accommodation are only rarely received by the Public Relations Officer. The conclusion is that the luggage observed during the survey represents, nearly enough, all that passengers wished to have with them.

For the purposes of the investigation "a piece of luggage" was defined rather vaguely as any article which a passenger might reasonably expect not to have to support on his lap during the journey. With this convention, central buses and trolleybuses carry one piece

of luggage to every 33 passengers on weekdays (winter and summer) and about twice this amount on Saturdays in August, the height of the holiday peak. The corresponding figure for country buses is one to 20, and for coaches, one to every four or five passengers, and half as much again on Saturdays in August. These figures are average for the whole of the respective fleets. The amount of luggage carried on each bus varied considerably, and roughly half the buses boarded by the inspectors carried none. The quantities given in the following Table were not exceeded in more than one vehicle in 100, except at the height of the holiday peak when no more than three vehicles in 100 carried more.

Service	*No. of average "suitcases"*
Double Deck Central Buses	6
Single „ „ „	4
Trolleybuses	5
Double Deck Country Buses	5
Single „ „ „	6
Single Deck Coaches (34 seats)	10
„ „ „ (39 seats)	11
Double Deck Coaches	8

Although it is almost always possible to find room for all passengers' luggage, there may be some obstruction of the gangways, and it is desirable that there should be sufficient space clear of the gangways to stow a quantity of luggage which experience shows to be exceeded but rarely. This requirement is interpreted in a recommendation that future designs of vehicles should be provided with sufficient accommodation for the amounts of luggage given in the table above.

ABSTRACTS

Input-output Economics.

WASSILY W. LEONTIEF.

Scientific American, October, 1951, **185** (4), 15-21.

The relative speeds of advance of the physical and the social sciences have often been contrasted to the disadvantage of the latter. The reason for this may lie largely in the difficulty of experiment in the social sciences, which tends to encourage the development of a theoretical system untested against reality. As far as economics is concerned, however, there has not been lately a want of data, but rather no means of reducing the immense mass of data available to a form to which the tools of traditional deductive analysis can be applied. This article concerns a new method of representation which can portray both an entire economy and its fine structure by plotting the production of each industry against its consumption from every other. The modern high-speed computing machine, plus the present propensity of government and private agencies to accumulate mountains of data, has made the method practicable, and it is now advancing from the phase of academic investigation and experimental

VOL.
3
1952

trial to a wider sphere of application in problems of national economic policy. The central concept of this input-output analysis is the idea that there is a fundamental relationship between the volume of the output of an industry and the size of the inputs going into it. This relationship can be expressed on a matrix diagram in which the inputs from, and outputs to, all industries in the economy are recorded on the horizontal and vertical scales. Theoretically this could, of course, be applied to all economic units, but in the example given for the U.S. economy in 1947 these are grouped in 42 major categories. Detailed analyses for individual industrial groups are given from other years to facilitate comparison over time.

Post-war Developments in Operational Research.

A. W. SWAN (Courtaulds Ltd.).

Engineer, 21st December, 1951, **192**, 812-814.

Mr. Swan states, as his own view, that the essentially new feature in operational research which distinguishes it from the pre-war concept and practice of "scientific management" is the use of present-day statistical methods. The tools of statistical analysis may be used to examine the present position by means of quality control charts, sampling schemes, time studies, etc., and these may all suggest means of piecemeal improvement. The Fisherian-planned experiment, however, may take one further and suggest more radical alterations to production procedures. When control chart methods are used not merely as static indications of the present position but as pointers to better practice, "there is justification for the view that they are being used as operational research."

The experience of setting up an Operational Research Department at the United Steel Companies is then described in some detail. The qualifications of senior personnel (degree in physics, chemistry, mathematics, metallurgy or engineering) and their personality requirements (pleasant, firm, tolerant, sense of humour) are set out, and the reasons for these, in terms of relationship with the practical men, are emphasised. A previous knowledge of statistics was not considered necessary.

Initial scepticism was gradually overcome, and the aims and methods of the new section were communicated in private conversations, lectures, and experience in practical problems. Finally, an actual investigation concerning a too-high percentage of rail defectives is described in detail.

Administrator and Specialist.

H. A. C. DOBBS.

Corona, Nov., 1949, **1**, 7-11 ; *Dec.*, 1949, **1**, 18-22 ; *Jan.*, 1950, **2**, 2-6 ; *Feb.*, 1950, **2**, 64-66.

In this stimulating series of four articles Mr. Dobbs considers the relation between technical and executive authority — primarily in relation to colonial administration. The familiar dilemma springs from the fact that the administrator has to control and co-ordinate what he often cannot understand, while the very qualities and aptitudes

which go to make the first-class scientist or technician may actually make it more difficult for him to do successfully the job of an administrator. This gap, which the increasing technological complexity of the welfare state tends to widen, can be succesfully bridged, as it was during the war, by operational research regarded as an organ of government. This new organ must help the administrator to integrate the specialisms of modern technology, and to act sometimes without reference to the established hierarchical levels of a bureau system. Such operational research need not be only quantitative but may also be applied qualitatively to problems of the machinery of administration itself. The final conclusions reached in the paper as a whole are : first, there is a need for a re-orientation in the relations between administrators and specialists in colonial governments to enable the most effective use to be made of limited resources in carrying out the objects of the welfare state. Second, this necessary re-orientation will require changes in the functioning and structure of the administrative machine, similar to certain developments in the United Kingdom, involving operational research techniques, introduced as a result of war-time experience.

Purchasing: Optimum Size of Order (" How Much Shall I Buy? ")

MARY S. MUNN and SARAH M. HAYWOOD (Imperial Chemical Industries).

The Purchasing Journal, Jan., 1951; **7** (1), 11-16 *and Mar.,* 1951, **7** (3), 99-104, 113.

The optimum size of order given for regularly bought components is considered in a study made by the Central Purchasing Department of I.C.I. A formula, based on the variable cost of ordering and stock holding, was developed to calculate the optimum purchase quantity. It is then shown how acquisition costs increase as the order quantity increases above the optimum. Two formulæ are derived for determining: (i) The minimum acquisition cost in pounds; and (ii) The rate of increase in acquisition cost when a quantity other than the optimum is purchased. From these formulæ it is shown that the saving achieved by increasing order quantities to obtain a quantity discount might be offset by the increased acquisition cost. It is possible to construct a graph on log-log paper to indicate the increase in order quantity that is economic for various percentage discounts. Sample graphs are reproduced.

Standards of Service in Transport.

A. B. B. VALENTINE (London Transport).

J. Inst. Transport, 7 *Nov.,* 1951; **24** 247-255 and 258.

In this presidential address to the Institute is considered the meaning of the phrase " an efficient, adequate, economical and properly integrated " system of transport which the British Transport Commission are enjoined to provide by the Transport Act. Particular difficulty is found in defining " adequate " and " economical," and it is pointed out that there is no ready measure of adequacy with a

VOL.
3
1952

particular service, since the service must satisfy all classes of traveller. Generally, the public expect the possibility of better service at lower cost. At the extremes, a totally inadequate service may be provided at small cost in which case all complaints will refer to the bad service; or an excessively luxurious service is provided at high cost and complaints will refer only to the cost. If both types of complaint are received, the service is probably about right.

O.R. is suggested as a method of helping to solve many problems in transport management with particular reference to the achievement of economy by improved efficiency. An explanation of O.R. is given, and some examples of suitable problems given. It is pointed out that old-established methods developed from experience are not often proved wrong by O.R. Nevertheless, it is of great value to supplement "know-how" by "know-why."

Keeping Quality and Raw Milk Grading:

Dye Tests as Measures of the Keeping Quality of Milk.

A. ROWLANDS (National Institute for Research in Dairying), H. BARKWORTH, ZENA HOSKING and O. KEMPTHORNE.

The Effect of Storage on the Results of Keeping Quality and Dye Tests.

R. T. EDDISON, O. KEMPTHORNE, ZENA HOSKING, H. BARKWORTH, C. P. COX and A. ROWLANDS.

Comparison of Keeping Quality Tests and Dye Tests in Milk Control (Results of a Field Trial).

A. ROWLANDS and ZENA HOSKING.

J. Dairy Research, June, 1950, **17** (2), 159-191; *Feb.,* 1951 **18** (1), 43-71; *June,* 1951, **18** (2), 166-192.

These three papers describe work undertaken for the Ministry of Agriculture and Fisheries to determine the best method to be applied for the routine testing of milk and to consider the possible application of a grading scheme.

Put in a very simplified form, the ultimate object of a testing scheme would be to ensure that milk of very poor keeping quality does not reach the consumer. Commercially, the end-point of milk keeping quality is when the milk turns sour, and under normal conditions this will be long after it leaves the producer, and it should be long after it is delivered to the consumer. A testing scheme therefore requires a test which can anticipate the normal end-point of keeping quality, if possible before the milk is bulked at the dairy, since one poor churn may then spoil the whole; for a grading scheme involving some form of quality control of each producer a quick test is not so important, though it still remains administratively desirable. Finally, since the tests must be conducted in the laboratory, the producer must be protected from abuse of the milk from the time it leaves his control at the farm gate up to the time of testing.

The first paper describes experimental work which was undertaken to compare the results obtained by the various methods currently employed for testing milk; these include the clot-on-boiling test, the methylene-blue and resazurin tests, and the alcohol precipitation test. To speed up these tests, the milk is normally incubated at an enhanced temperature (up to 37.5° C.) before testing; the resazurin test differs from the others in that it is a dye which decolourises gradually and

a colourimetric test (disc number) can therefore be applied at a very early stage. In these experiments samples of milk from normal production were specially collected from farms; the laboratory tests were carried out in the routine manner except that end-point tests were made at frequent intervals so that an exact determination of the end-point was made. The experiments and conclusions are described in detail. The most important conclusions are that incubation at 37.5° C. (the temperature normally applied at present) gives unreliable results, although incubation temperatures of 18-22° C. are better. The resazurin disc readings are an unsatisfactory measure of keeping quality, although no alternative quick measure is suggested.

The second paper describes further experiments of a similar nature to determine the effect of the temperature of storage of the milk from the time it leaves the farm until it is put on test at the laboratory. A formula is derived whereby an adjustment can be made for the atmospheric temperature while the milk is being carried from the farm. In this way, the test should be of equal severity for all farmers and at all seasons. The formula is found to apply better for clot-on-boiling than for methylene-blue test; in particular, inaccuracies arise if the samples for the latter are not inverted at frequent intervals during test. This means that the methylene-blue test must be under constant supervision, whereas the clot-on-boiling test can be carried out entirely automatically using a special bath described in the third paper. This is an important administrative point, since the routine employment of night staff could be avoided.

On the basis of the experimental results a possible grading scheme is suggested, and in the third paper, results are quoted of a field trial in which this scheme is applied in comparison with existing routine methods.

REVIEWS.

Applied Statistics—A Journal of the Royal Statistical Society.

Quarterly. Price 1s.

THIS new journal of the Royal Statistical Society has been founded, according to the foreword by the President, Dr. Bradford Hill, "to meet the needs of all workers—not of professional statisticians only, but also of those innumerable workers in industry, commerce, science and other branches of daily work, who must handle statistics as part of their tasks. Its aim, in short, is to present, in one way or another, but always simply and clearly, the statistical approach and its value, and to illustrate in original articles modern statistical methods in their every-day applications."

This is, indeed, a formidable task. There is perhaps no other subject, with the possible exception of psycho-analysis, in which the enthusiasm of its devotees is matched by such baffled hostility from so many of those to whom its assistance is offered. The experience of this hostility—it goes much farther than apathy—is distressing to the statistician working in the industrial field; especially when he comes into contact with so many who, while knowing nothing of statistical methods, nevertheless have to interpret numerical data as part of their daily work. To attempt to bridge this gap is laudable, and the Council

VOL.
3
1952

of the Royal Statistical Society have been fortunate in having secured L. H. C. TIPPETT as the editor.

A first impression of the contents of the first issue (in itself, of course, too limited a sample for adequate judgment) is that the articles are concerned with a wide variety of statistical methods and their industrial and social applications. To comprehend them all would need already a fairly advanced knowledge of the subject. If the wide audience, to which the journal is addressed, is to be not only captured but maintained, considerable care will have to be exercised in judging the "depth" of articles published, perhaps by relegating more advanced theory to appendices. It may be better for the more advanced statistician to be left demanding more knowledge (which he can find from references) than for the non-professional to be left unable to assimilate what he has been given and only too ready to conclude that statistical methods are not for him. No doubt the experience of Mr. Tippett will lead the journal to a solution of its problems—a problem which is as difficult as its solution will be valuable.

A Treatise on the Accuracy of Time Standards for Human Work.
J. R. DE JONG.
Published by Tempo, Hengelo, Holland, 1951. *(In Dutch, with an English summary.)*

IN the introductory chapter to this treatise, Dr. DE JONG points out that the "forecasting" of the operation times of a proposed production process has two main objects :—

1. Production Planning.
2. Performance measure
   (a) to fix payment by results ("rate fixing");
   (b) to influence performance for the better (incentive schemes).

To achieve these objects time studies are undertaken, but previous literature ignores two main questions.

1. The means of assessing the accuracy of values determined by such studies ;
2. The number and extent of the studies that should be made.

The result has been that time study practice has found it difficult to hit a happy mean between uneconomical superfluity and unreliable fixing of job times. The present treatise, therefore, "is devoted to arriving at both the required (optimum) accuracy of time standards and the evaluating of the accuracy achieved. It treats further the (in)accuracy of estimated time standards and the effects of a number of wage incentive schemes on errors in time standards."

Chapter II concerns the "Computing of Time Standards from Time Studies," and Chapter III—"The Accuracy Required of Time Standards." The causes of variation in performance are considered in some detail, and common sampling theory applied to show the effect of these on the limits of accuracy of the time standards achieved. The number of studies to be made to reach a given degree of accuracy can then be assessed. It would have been useful had Dr. De Jong described in rather more detail the technique used in

gathering the raw data for what he calls a "fair sample"—how, for example, he gets over the difficulty that observation affects behaviour.

In the following chapter, "Measuring and Computing Errors," the distinction is drawn between random and systematic errors; data on the differences between observers is given, and fourteen guiding principles for performance rating are put forward. The statistical analysis and control of observations is discussed in further detail. Dr. De Jong then goes on to compare the accuracy of time standards based on such time studies with that achieved by standards based on estimation.

In his final chapter certain wage incentive systems used in the Netherlands are examined in relation to the measurement of time standards and the concept of optimum accuracy. It is difficult to comment adequately on these without rather more knowledge of the conditions pertaining than is given in the text. English and American experience would suggest that the performance of operators is dependent on other factors than wages, and that consideration of the wage factor in isolation may be misleading. This is, however, not to decry the use of wage incentive schemes, and the dissatisfaction often expressed with rate fixing methods in use points to the need for accurate time standards in such schemes.

There is a statistical appendix and a bibliography.

Basutoland Medicine Murder: A Report on the Recent Outbreak of "Diretlo" Murders in Basutoland.

DR. G. I. JONES.

H.M.S.O., London, 1951, *Cmd.* 8209, *pp.* 104 + vi. 2 *illus.*, 1 *map.* 3*s.*

This is the report of the anthropologist commissioned to study the causes and possible ways of preventing Medicine Murders in Basutoland. Chapters V and VI describe how, through the strengthening of the chiefs' authority, the structure of rule had become rigid, while economic advance and polygamy had led to the creation of an excessive number of minor chiefs and headmen. In an attempt to improve matters, the Government had in 1937 begun reforms, without, however, studying the actual situation. Dr. Jones shows how various lists of chiefs and headmen failed to agree with one another, and how some changes, instead of reducing the number of lesser chiefs, increased them. Moreover, arrangements intended to reduce the imposition of unpaid tasks on the average African were shown to appear in practice as a higher tax demand with little to show for it. Particularly because the reforms were introduced from the top down, they have been misunderstood, and have "revolutionised the Basuto political system much more than is realised locally." Though the main point of this part of the enquiry is the demonstration that the reforms had contributed to the feeling of insecurity which found its expression in the desire for medicines made with human flesh to improve the possessor's chances of improving or maintaining his position in the hierarchy, it is also an example of the study of the discrepancies between what the administrator intends and what occurs.

T.E.E.

VOL.
3
1952

OPERATIONAL RESEARCH QUARTERLY

VOL. 3 NO. 3. SEPTEMBER, 1952

Contents

Editorial Notes 37
Building Operations 39
O.R. in the Welfare State 50
Abstracts 51
The Operations Research Society of America 56

EDITORIAL NOTES

A Course at the Case Institute

When an executive takes a decision to institute operational research in his company, the first problem facing him is to find a suitable man for the job. Broadly speaking, he can choose between two alternative sources of supply; he can either hire someone who has O.R. experience but no knowledge of the company; or he can find some suitable man in the company and have him trained for the O.R. job. There are undoubtedly arguments for both courses, and which is adopted in any particular case will depend on local circumstances. It is sufficient to say that there will certainly be some cases in which the latter course will be preferred.

With the virtual certainty that there will be some workers gravitating into the O.R. field in this way, therefore, it becomes important that facilities for their training should be available. It was primarily with this in mind that a Short Course in Operations Research was held at the Case Institute of Technology from 16th to 27th June, 1952, organised by Professor C. West Churchman and Russell L. Ackoff of the Department of Engineering Administration. Being the first of its kind, this course was necessarily somewhat experimental.

The first difficulty, as with any course for participants of rather heterogeneous experience, was to decide on a common denominator of knowledge to provide a starting point. The solution adopted, after a study of the particulars provided by registrants, was to recommend an elementary statistical text book for preliminary reading, the first day of the course being devoted to a very rapid discussion of the most relevant points in the book with particular reference to types of distribution. On the whole this seemed to be satisfactory. The problem was the more difficult because a few of those taking part were in fact well-established O.R. workers who naturally found this start too elementary. Few, however, complained that it was too difficult. Indeed, it is hard to see how a course on O.R. could start with an assumption of less background knowledge than this.

The course itself was frankly methodological in intent with a liberal quota of practical example. Unfortunately, O.R. is not yet sufficiently established to avoid the necessity of explaining to newcomers in what sort of problems it can be useful as well as telling them how they can carry it out. There was, however, an admirable avoidance of digression into airy discussion of definitions of O.R. The policy was to let the methods and examples speak for themselves, and among the examples the war-time researches and other tales of yore did not obtrude. Indeed, the writer does not recall a single reference to them.

The course proper began with an excellent discussion of Research Design by RUSSELL L. ACKOFF. The subject was treated in its broadest sense and was not concerned with statistical design of experiments. Some of the matters dealt with included the elucidation of objectives and their weighting when there are conflicting ones, the use of operating characteristic curves to decide the best balance of risk between Type I and Type II errors, and the setting up of mathematical models.

Professor S. B. LITTAUER expounded on the value of simple control chart techniques in assessing the stability of production in a factory and in helping to determine the causes of instability. He was followed by Professor A. CHARNES and W. W. COOPER on the subject of linear programming; they showed how, once the matrix has been set up, the solution of the problem can be reduced to purely mechanical operations which can be carried out by unskilled labour.

Professor CHURCHMAN returned to the subject of mathematical models in connection with problems of scheduling replacements in maintenance and with optimal inventory (stock) policy. Symbolic logic and the theory of games were briefly introduced and the theory and value of sampling was also considered, with particular reference to the possible use of sampling in accounting; sampling was also considered by LEON PRITZKER, of the U.S. Bureau of the Census, who discussed conditions in which a sample may give more accurate information than a complete count.

Other speakers included Professor CLAY H. HOLLISTER, who stressed the increasing importance of marketing as compared with production in the final cost of the product to the consumer, and hence the big dividends which might be obtained by O.R. into marketing. JOHN B. LATHROP indicated some directions in which O.R. had been satisfactorily applied on a consulting basis. ROGER T. EDDISON referred to some of the work being done in England and found particular interest in applications of the theory of queueing.

The course ended with some brief remarks by two speakers from outside the field of O.R., Professors R. SCHANCK and T. COWAN, who considered the philosophical implications of O.R.

The general feeling among participants seemed to be that they had learnt much that would be useful to them. It is to be hoped that this first course will not be the last. R.T.E.

VOL.
3
1952

BUILDING OPERATIONS

by

J. F. EDEN

This article is based on a paper given by the author to the Operational Research Club in January last. It has been revised and brought up to date where necessary. It is published by permission of the Director of Building Research and describes work undertaken by the Building Research Station.

IN an article in this Quarterly for March, 1951, Mr. John Knox described the operational research carried out by the Government in the building industry and briefly described the methods which have been employed. The present article enlarges on certain aspects of the work, particularly those which deal directly with building work on the site.

The problem of increasing productivity and reducing cost in the building industry is a formidable one for a number of reasons. Its extremely large size is associated with a very heterogeneous character both as regards size of firm and efficiency. Even more serious from the point of view of development, is the fact that the industry is divided into a number of compartments, in a way which is not at all typical of other industries.

In the manufacturing industries the functions of design, estimating, layout of production, costing and marketing are carried out within a single organisation. In the building industry these functions are separated, both in terms of personnel and time, and this must inevitably be a great disadvantage from the point of view of economy and increases the difficulties of the operational research worker.

The first organised attempt to apply operational research to the building industry was made at the end of the war, when the inherent difficulties mentioned above were augmented by the fact that little building work of a normal character had been undertaken for six years.

The depth of ignorance about essentials was abysmal. There was no knowledge of the existing level of productivity in any house-building operation whatever. The only cost data available related to pre-war building by organisations which had so changed during the war that the figures were mainly of historical interest. They existed in no great detail and their accuracy was questionable. I remember at that time looking at two independent estimates, made by people of wide experience and great integrity, of the labour expenditure in building a brick house, and finding that one total was twice the other. Such a variation was, however, not surprising even at that time, because one of the few facts that was known was that building productivity, even in pre-war days, varied very greatly from builder to builder and from site to site. The degree of the variation was expected to be even greater immediately after the war. It is this

degree of variation in performance of the same task, due to the heterogenity of the industry and the variety of conditions in which work is performed, which presents one of the greatest difficulties to a study of building work in the field.

It was very quickly learnt that most of the man-hours and cost data relating to the building of one pair of houses were almost valueless. The experimental houses built at Northolt in 1944 and in ones and twos by licences issued under the guidance of the Inter-departmental Committee on House Construction, were therefore useful only in exploring techniques. They produced no figures of cost or labour expenditure which had any meaning.

Evaluating Performance

One of the first tasks to be tackled was to evaluate the performance of a number of different methods of house construction. Among these were different types of concrete houses, both cast *in situ* and built of precast units; some steel-framed and some timber-framed structures; some structures almost entirely built on the site, some employing a large measure of prefabrication.

It was decided to build 50 houses each by these methods on different sites, and to observe the construction in as great detail as was possible, so as to measure the labour expenditure house by house and operation by operation as work proceeded. The method of observation had to be simple, because there was no time for lengthy training, and it was also important to ensure that observation did not affect the performance of the work; that is to say the number of observers on each site was severely restricted, and they had to be as unobtrusive as possible. In an attempt to provide comparable data, the house was divided into main operational groups: foundations, external walls, roof, etc., which would be independent of the method of construction, and for each type a schedule of operations was prepared, in which each readily distinguishable operation was classified by a decimal system under these main headings. Observers were given a copy of these schedules, and two or more were stationed on each site. Each man had to record the number of men working on each operation every quarter of an hour on a specially designed form. Symbols were used to record, also, non-productive occurrences under a few main headings, such as work stopped by rain, work repeated, tea breaks, etc. Experience also showed that it was necessary to record a group of general operations, such as unloading, making temporary roads, etc., which could not be specifically allotted to particular dwellings and had to be observed in lots and apportioned to each house at a later stage.

A number of sites of traditionally built houses were also observed in this way, in order to discover the range of performance in traditional building, and to provide data, which could be subjected to statistical analysis and give information against which to measure the results from the less traditional sites.

Altogether about 20 sites were observed averaging about 50 houses

VOL.
3
1952

on each site. As each house had 60 or 70 different operations and work was also recorded under trade headings, the number of sub-totals ran into hundreds of thousands. To them must be added the machine hours later observed and the quantity and cost of all materials. The analysis of this mass of data was a large task. Some of the difficulties which have to be met when comparing different systems of building construction may be of interest.

In comparing the results of an experiment in which 50 houses are built by the inventors of each of two methods there are many contributing factors. For example, there is bad weather. This can be overcome by building on the same site over the same period of time. Then there is the question of the degree of effort involved. It is possible to put a figure on this by carefully watching certain operations which are the same in one house as the other. But one part of the site may be very different from another. For instance, one may be hilly, or swampy, with no roads, while the other is flat and dry with good access. Then there is the matter of experience. If one inventor is a more experienced builder than the other he will probably get better results anyway. At this stage we might well stop and ask ourselves exactly what we are trying to find out. Are we trying to prove that one inventor is a better man than the other, or are we trying to find out what will happen, in the future, if two types of house are given to builders to build? If the latter is our aim, we must try to exclude the influence of the individual inventors from the experiment. We cannot do this by seeing that both have nothing to do with it, because then the data would never be obtained, but we may learn something from a study of the "improvement curves" on each site. We have found on each site that we have observed, that there is a reasonably steady improvement as work progresses. The results from a large site are, other things being equal, better than on a small one, due to this improvement. If we plot man-hours per house against the order in which they are built, we get a curve, which starts to slope steeply downwards and then flattens out. When we compare our two sites, therefore, we must compare our results on the flattened portion of these curves, but we must also take into account the shape of the beginning of the curve because this might give some indication, other things being equal, as to how quickly other people can be taught to organise the building of the two types of house, and for what size of site they are most suited.

There are, of course, any number of other factors which have to be taken into account, and observations must take place in the factories where the components of the two houses are made, as well as on the site. The comparison of performance of building is in fact a very complicated process, and we have by no means perfected our methods. We know now, however, that we made many mistakes in our early experiments, which prevented us from learning as much from the results as we might have done, and in

future we shall use a more carefully designed statistical plan in order to be able to measure the effect of site to site variables more accurately. In spite of this, these early experiments were successful. We were able to evaluate the performance of the non-traditional houses studied and make prognostications as to what would happen when they were built by other people, which have turned out to be fairly accurate.

Superstructures

How the average productive times for building house superstructures of different types varies according to type is shown in Fig. 1. This is not just a record of what happened on the sites we observed. It is a forecast of what will happen if houses are built by the methods in large numbers on sites of 50 houses. For instance, if all builders in the country built type 3 instead of the traditional type, the average saving in labour expenditure per house superstructure would be about 300 man-hours. Such a conclusion is of

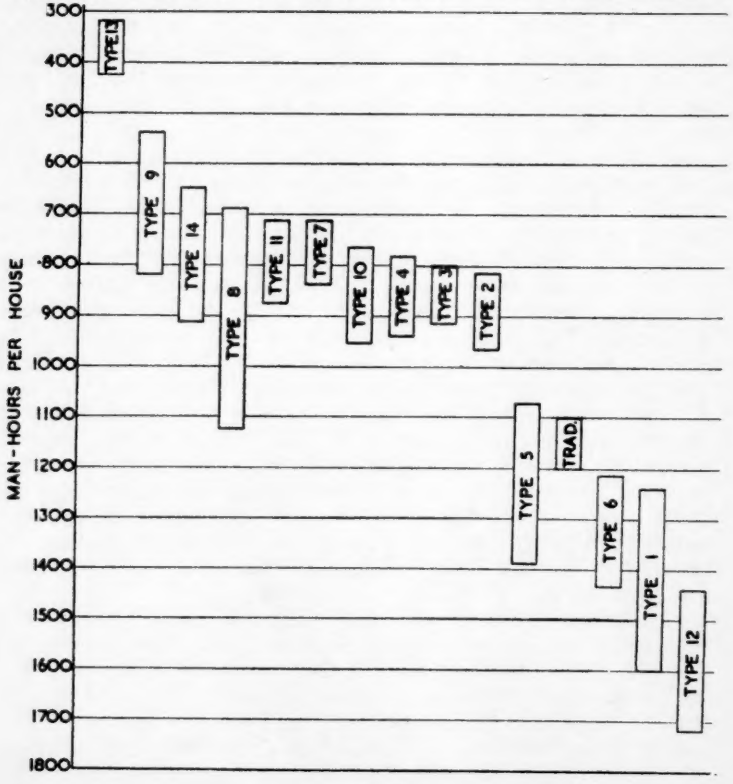

FIG. 1. PRODUCTIVE TIMES FOR SUPERSTRUCTURE

VOL.
3
1952

great assistance in forming policy. As, however, the range of labour expenditure for traditional superstructures is much wider than is drawn here, the chart is not quite as much help to an individual builder, particularly if he operates in a small way. He cannot say that by changing to type 3 he will save 300 man-hours per house. He can only say that his labour expenditure is likely to be considerably less than when building traditionally; in fact, that the order of performance shown in Fig. 1 should apply to him, but not necessarily the figures up the side.

The labour expenditure on building the superstructure is not, of course, the whole story about the house. Summarising the findings of these experiments, we can say that the best methods of construction examined saved up to 40 per cent. of the manpower in the parts of the house to which they were applied. They were, however, only applied to about one-third of the construction of the house, so that the saving in terms of the whole house was not more than 20 per cent. at the best. In terms of cost, it was shown that although no large savings had been achieved, the best methods were capable of being slightly cheaper than the traditional type if produced efficiently on a large enough scale.

These results have been borne out in practice. About 145,000 permanent non-traditional houses have been built in this country since the war, or about 20 per cent. of the total number of permanent houses built by local authorities. The more successful of the types examined have contributed largely to this figure, and have been among the cheapest. Further developments are improving the figures of cost.

Whole Houses

A study of the results of these experiments indicates the possibilities for the future. Such savings as were achieved have been realised by the introduction of new methods of construction for the walls and the walls only. It is clear that if similar methods could be applied to the remaining two-thirds of the house, we might expect very much larger savings. Can this be done? The methods successfully used in the walls were as follows:

(*a*) Saving in cost of materials by using smaller quantities of cheaper materials.

(*b*) Savings in site labour through prefabrication.

(*c*) Savings in site labour through rationalisation of site work and the introduction of machines.

To discuss how these methods might be applied to the whole house, it will be of interest to examine some of the figures from traditional sites. Fig. 2 shows the man-hour expenditure on typical sites observed at that time. The first point to remember is the extremely wide range in practice, the highest being about three times the lowest over all sites. There are many contributing reasons for this, but the biggest single factor is that imponderable thing, the quality of the site organisation.

The organisation required to build a series of traditional houses economically is exceedingly complex, and in practice it is very difficult to do well. There are 60 to 70 different operations utilising seven or eight quite different trades as well as semi-skilled men in several different capacities, and general labourers. The work cannot be passed from man to man, the men have to move to find the work. None of the separate groups of men have equal amounts of work to do and continuous employment can only be achieved by complicated and difficult gang relationship. All this means that to build one house economically, it is necessary to have a relatively large number at some stage of construction, either on the same site or on others. The most important lesson to be learnt from this is perhaps not so much the need for the training in organisation, although this is of course very important, but the absolute necessity

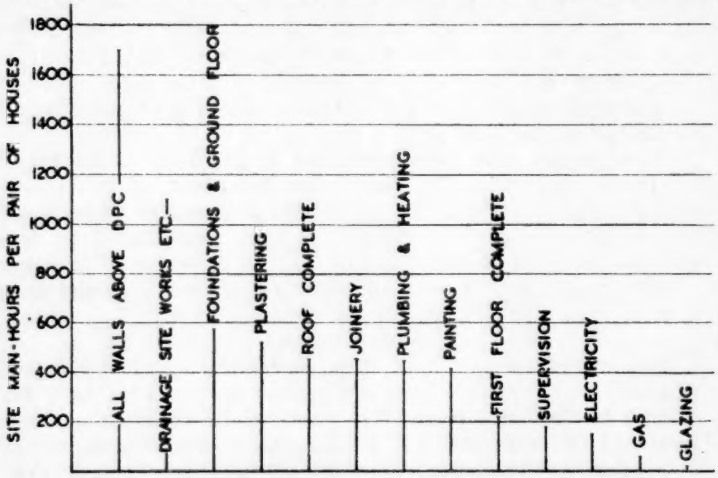

FIG. 2. SITE MAN-HOURS IN BUILDING SEMI-DETACHED BRICK HOUSES.

of simplifying the building process, so that the organisation will not require supermen to put it into practice.

It might be thought that these wide variations are due in great part to the special difficulties to which the industry was subjected directly after the war, but in fact we find that a similar wide variation is occurring today.

We have not, of course, been able to repeat our detailed observations on the scale of those originally undertaken, because of the staff and time required, but we have been able to make periodical checks on group totals by using another method, which enables us to detect changes in the level of productivity of the main components of the house. This is a sampling method, carried out with the co-operation of selected firms of builders of different size, all over the country, whose cost records are examined and confirmed

VOL.
3
1952

by spot checks. The latest of these productivity surveys discloses that the total range of man-hour expenditure per house over the 150 or so sites observed was from 1,600 to 4,725 man-hours. This covered a period up to June, 1951.

When dealing with such wide variations, it is, I think, idle to talk in terms of averages, but a great deal can be learnt from a study of the proportion of total building time expended on various operations and groups of operations. For instance, in Fig. 3 I have divided the figures for the latest productivity survey into three main tasks.

The first of these, comprising everything under the ground floor, can be greatly improved by more economical design, using less materials and using more machines. Prefabrication cannot help very much.

For the second task, that of building the walls and roof, we know

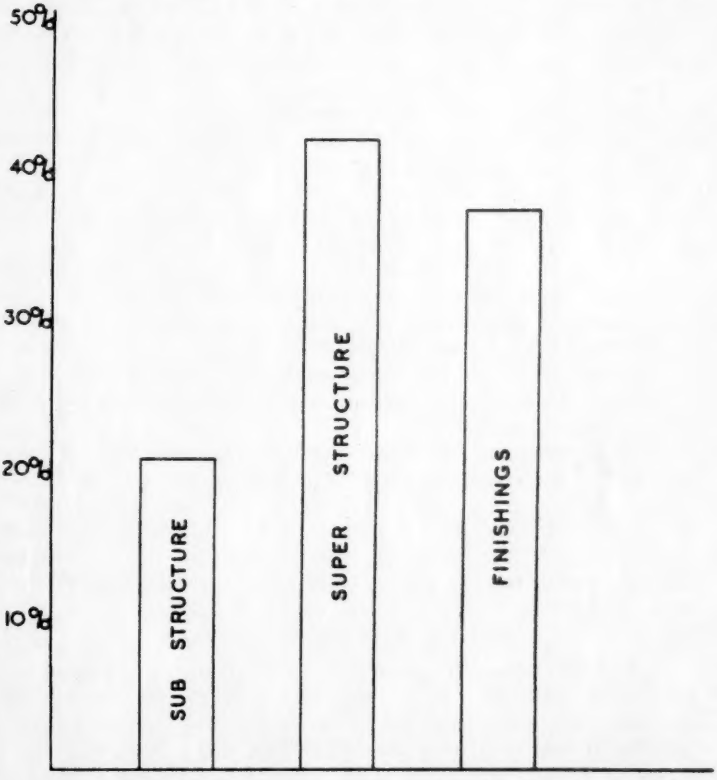

FIG. 3. PROPORTIONS OF TOTAL LABOUR EXPENDITURE IN BUILDING A HOUSE IN 1951, UNDER 3 HEADINGS.

that substantial economies in time and smaller economies in cost can be made by applying several different non-traditional methods which are now well proved. Some of these rely on prefabrication, but results which are just as successful have been achieved by relying on the use of mechanical plant on the site. At the end of this task, 90 per cent. of the weight of materials in the house have been built in. It is in these first two tasks, therefore, that we might expect to get the most benefit from handling machinery.

The third task we may call the "finishings." It is about as big as that of the super-structure. A number of time consuming operations involving five or six different trades has to be carried out in a complicated sequence in circumstances where there is insufficient room to employ large gangs. In the main, it is the complexity of this group of operations which produces the organisational headaches, and it is this task which offers the greatest scope for simplification. We feel that as much of the work as possible should be carried out in a factory, where the problems of organisation can be more easily dealt with. The factory, of course, may be on the site or off it.

The solution of this part of the problem appears, therefore, to be largely a matter of design, the object being to evolve a type of house in which the whole of the internal linings and fitments can be completed in a factory in such a way that they can be built into a site-built structure without difficulty. This is not the occasion to go into details of the designs which are the subject of present experiments, but the problem can be tackled in three ways:

(1) Improvement of structural units forming the walls, so that no lining is necessary. The main problem is to avoid creating more work on the site when the services are installed.
(2) Provision of cheap factory-made units to fit inside the site-built shell. Here the main problem is to make them fit.
(3) Provision of lining panels which are erected prior to the building of the shell.

Each of these methods means some alteration to normal building practice and we have to consider not only which gives the best results in a given set of circumstances, but which can be most easily introduced and accepted by the great variety of firms which comprise the industry. At this time, pilot experiments favour the third method, but these results may, of course, be reversed when trials are extended to building sites.

Mechanical Plant on the Site

It has been observed earlier that the greatest scope for the use of mechanical plant on housing sites lies in the building of the sub-structure and the walls and roof. This is basically a handling problem and the experimental work which has been and is being done at the Research Station into the field of materials handling is based upon the analyses we have made of the recordings from traditional housing sites mentioned earlier. These have been augmented by later pro-

VOL.
3
1952

ductivity surveys carried out by the examination of the cost records of a statistical sample of builders throughout the country, and also by a wide use of time study for detailed analyses of particular operations and for comparisons. An example may be given as follows :

A study of the original records from fifteen or twenty different sites showed that the foundation and ground floor of houses involved costs varying from £120 to £250 for labour and plant, and a labour expenditure of from 270 to 540 man-hours. A major operation in the work is the mixing and placing of concrete using a concrete mixer and wheelbarrows. Teams varied from 6 to 13 men, barrow runs from 10 to 50 yards, output from 1 to 4 cu. yds. per hour, productivity from 0.1 to 0.37 cu. yds. per man-hour, and costs of labour and plant from 10s. to 30s. per cu. yd. There appeared to be no relationship between these variations ; all one could say was that the best results were obtained on sites reported to be well organised, and also on sites where the work on concreting was reasonably continuous.

The first attempts made to study the operation in detail disclosed the importance of continuity, since about 25 per cent. of the labour was expended in starting up the jobs and closing them down. A number of time studies disclosed that part of the variation could be accounted for by wrongly constituted teams, and showed that the organisation of these teams was fairly complicated. We were, however, able to establish certain simple rules for determining the number of men required to push wheelbarrows. For instance, with a concrete mixer producing 7 cu. ft. of concrete in a batch, operating with all normal lengths of barrow run, three men produce the cheapest team and six men the quickest. These rules can be applied on any site. More important still, we found that even with the best organised teams, the use of wheelbarrows only enabled the mixer to work to about 70 per cent. of its capacity, and that this could be regained by using a large container capable of taking away the whole batch from the concrete mixer in one operation. We could set down or write a specification for the machine required. At this stage we tried to get manufacturers to produce something, but no one was the slightest bit interested. We had to produce more "bait" and by 1948 we had three rather extraordinary looking prototype machines at work on building sites and actually lowering costs, in one case to 3s. 7d. per cu. yd. as against the range mentioned above, of from 10s. to 30s. Such a comparison is, however, not justifiable. The low figure was obtained on one site with a number of peculiarities ; the range covers the whole country. How can we obtain better comparisons? Our attempts so far, with which we are not at all satisfied, comprise a mixture of normal time studies and common sense. Even so, we have to take very great care both in the selection of sites and in the interpretation of the results, and even a fairly simple comparison may involve trials at three or four sites over a

period of months. In the case mentioned above, the comparison finally achieved was on the basis of normal conditions of site, quality of work and effort, and the figures were about 5s. 6d. per cu. yd. with the machine, and 9s. 6d. with wheelbarrows.

Interesting the Manufacturers

Our experience is that a development project of this kind is rather like making a snowball. You do a lot of work on paper, building up your snowball, but no one is the slightest bit interested. As your development proceeds, the snowball gets bigger and interest awakes. There comes a stage in any project when a slight push in the right direction sends it downhill, gathering speed, and there is no need to run after it. The case quoted above is in point. In 1947, although we knew the answers, we could convince no one, and there was even a certain amount of criticism of our work. At the end of 1948, one manufacturer was biting. By 1951 there were nine different manufacturers producing machines of this type, which were being exported all over the world.

The development of mechanical plant for building has always to be conditioned by the ability of the industry to accept them. Builders are not used to using mechanical plant and do not naturally think in terms of it. This applies also to architects. Our first task after the war was to break down a prejudice against any form of mechanisation. We have done this by encouraging the introduction of a number of small and inexpensive machines, which show a modest saving on particular operations without seriously affecting traditional methods of work or design. For example, a first glance at the latest productivity survey shows that about 30 per cent. of houses are built with the aid of mechanical mobile hoists or elevators for carrying bricks and mortar—machines which have been introduced since 1946. To go further, it is necessary for builders and architects to think differently—to think in terms of building houses mechanically rather than in terms of using machines to carry out operations which have hitherto been done manually. There is, for instance, a great volume of work in building a pair of houses which can be grouped under the heading of lifting and carrying. It occupies on the average about 550 man-hours, costs about £80 at present labour rates, and involves the moving of some 286 tons of materials. The problem of mechanising the work is made difficult by its extremely varied character, the wide area over which it takes place, and the slow rate at which materials are consumed. This points to the need of a very adaptable handling machine, to transport all materials vertically and horizontally over a wide area with few men at low cost.

Use of Cranes

Our researches tend to show that the type of machine most likely to be suitable for the work is a light crane with a very much longer reach than is normal, and a high degree of mobility ; and it is possible to write down a specification for such a machine with a fair degree

VOL.
3
1952

of precision. We find machines roughly conforming to this specification, but rather too big and too expensive, in the electric rail-mounted tower cranes which are used very extensively on the continent for large buildings, and which are now beginning to find their way into this country.

Given such machines, it is possible to calculate what alterations would be required to normal house building methods to enable them to be used effectively. Means have to be found to increase the speed of building house structures to keep the machine working economically. We have taken as an example the smallest continental tower crane we can find and have carried out tests on it at our experimental station. From the results we have been able to work out a plan for using it on a typical house-building site. By increasing the size of bricklaying gangs considerably, we have shown that it should be possible to reduce very considerably the proportion of unskilled labour and build house shells at something like three times the normal speed.

There would be savings in three directions :—

(*a*) Directly, in reducing handling costs (a potential saving of up to 400 man-hours per pair).

(*b*) Indirectly, in enabling a better balance to be achieved in the organisation of gangs on the site (reduction of process allowance)

(*c*) Saving in overheads due to building faster.

Estimates show that the total of these savings could be as high as £100 per house, if full efficiency could be obtained. Even at the lower efficiencies likely in practice the potential savings are still substantial.

We hope to put the plan into practice on a house-building site in the near future.

If we can achieve the introduction of a crane which is really suitable for house building, and show that this can save money and time in building houses of traditional character, I think it will open up very wide fields for future development. Once this has been accepted, it is a short step to building in larger units, prefabricated in a factory, or even on the site. The way will indeed be very much clearer to the integration and application of the results of our operational researches in design and method over the past few years.

Summary and Conclusions

To summarise what has been said : operational research in building in this country offers a very wide scope. The work that has been done has been, in the main, confined to the activities of government research stations since the war. A great deal of very important data on building methods and efficiency has been accumulated, related chiefly to house building, and an analysis of the data has fairly clearly established the major problems which have to be tackled. Present methods of building houses require an organisation on the site which is too complex for efficiency, and great advantage would accrue from

a simplification of organisation. The two main weapons are mechanisation and prefabrication, and the effective use of these means alterations to organisational methods as well as design. The greatest effects will come from the prefabrication of the "finishings" of the houses, and from the use of mechanical plant, particularly handling machinery, on the site in the construction of sub-structures, walls and roof. In both these fields, pilot stage experiments have already been carried out which show the way ahead and enable some tentative measurements to be made of the savings which might be achieved.

APPLIED STATISTICS

It is regretted that in our review of the new journal named above the price for each part was given as 1s. instead of 10s. The prepaid annual subscription is 25s. (U.S.A. $4) for three issues. The publishers (for the Royal Statistical Society) are Messrs. Oliver & Boyd, Ltd., Tweeddale Court, Edinburgh, 1.

O. R. IN THE WELFARE STATE

Our recent editorial note on the need for operational research on the effect of food subsidies finds an echo in *The Times* of 16th July, 1952. Under the title *Facts for the Health Service,* a leading article castigates the social services, in contrast to industry, for tending to regard operational research and the appraisal of results as superfluous. The Health Service, which probably has most to gain from operational research, is one of the worst in this respect.

After drawing attention to the paucity of published statistics, the article shows that even where the data are published investigations may be so badly conceived that they lead to faulty conclusions. The leader concludes:

> "Properly done, periodic studies of the experience of the 'consumers' of medical care—provided they are adequately related to the experience of 'producers' of medical care—are a necessary instrument for gauging the strong and weak points of the Health Service and the nature of the demands made upon it. They should not be undertaken except as part of a programme of operational research the purpose of which has been clearly thought out. Too much of what passes for official research into the workings of the Health Service has been marred by the failure of those responsible to ask themselves precisely what they wanted to find out and why."

OPERATIONAL RESEARCH CLUB

The Committee of the Club for the 1952-53 session will be:

Dr. T. E. Easterfield.
Mr. D. Hicks.
Mr. A. W. Swan.
Dr. O. H. Wansbrough-Jones.

VOL.
3
1952

ABSTRACTS

Operations Research in Business and Industry.
RUSSELL L. ACKOFF (Case Institute of Technology).
Industrial Quality Control. May, 1952; 1-8.

The nature of O.R. is discussed and it is pointed out that existing definitions are inadequate for distinguishing it from other kinds of research. O.R. is not distinguished by its objective nor its subject matter, but by the methods it employs and by the scope of problems these methods enable it to attack. O.R., more than any other type of research, is concerned with the development and use of measures of efficiency of a proposed solution to a problem. The relation between the O.R. worker and other types of industrial research workers is likened to that between the architect and the engineer.

Five principles of research procedure applicable to O.R. are considered :

1. The principle of measurement. O.R. deliberately attempts to invade non-quantified areas and introduce methods of measurement.
2. The operational principle. O.R. takes into account not only the one who makes the final decision but also all those who carry out the decision and are affected by it.
3. The feed-back principle. Research does not end with the selection of a proposed solution, but the proposal is evaluated in use.
4. The co-operative principle. The research team will include workers from many different scientific disciplines.
5. The practical principle. Each phase of the research is evaluated relative to the research objectives. This requires explicit formulation of the objectives.

Piece-work in Reforestation.
U. HELMERS and I. BYRNAS.
S.D.A. Report No. 43. 1952 40 *pp.* (*Swedish with English summary.*)

The report describes an investigation carried out by the Mo och Domsjö AB. in 1949 and 1950 to determine the effect on work output and costs of manual reforestation of introducing a piece-work system.

The experiment was carried out with " representative " workers in varying types of terrain and using a number of different equipments. Time studies were made to determine effective time per 1,000 furrows, etc., and it was shown that productive time (i.e., effective time plus time of delays not caused by the worker) was 20 per cent. greater than effective time. The workers were paid on the basis of this productive time and the piece-rate was fixed at 25 per cent. higher than the time-rate to compensate the worker for increased productivity.

The average increase in earnings per time unit was 22 per cent., and the company's costs were decreased by 14 per cent.

Appointment Systems in Hospital Out-patient Departments.

BRIGADIER J. D. WELCH (Nuffield Provincial Hospitals Trust) and NORMAN T. J. BAILEY (Cambridge U. Medical School).

The Lancet. 31*st May,* 1952; 1105.

Out-patients visiting hospitals may often be kept in the waiting room for more than an hour before seeing the consultant. This state of affairs has arisen because it has always been considered overridingly important to ensure that the time of consultants is never wasted. It represents a serious waste of patients' time, however, and also requires an excessive provision of waiting room accommodation. This report considers whether a suitable appointments system can reduce patients' waiting time without wasting the time of the consultants.

Studies are described of two functions which play an important part in determining waiting time, i.e., punctuality and consultation time. Punctuality of patients is found to be good, patients on the whole tending to be early rather than late. Consultants, on the other hand, tend to be late. The length of consultation time is very variable, but is found to conform satisfactorily to a Pearson type III distribution.

The mathematical theory of queues does not appear to provide a general solution relating consultants' idle time to patients' waiting time in these conditions. Quasi-empirical methods were therefore adopted, random numbers being used to select consulting times from the theoretical distribution. A curve is shown, derived in this way, relating consultants' idle time to patients' average waiting time for varying numbers of patients present at the start of the clinic, succeeding patients being given appointments at intervals equal to the mean consulting time (in this case 5 mins.). It is found, for example, that if there are two patients present at the start of the clinic the consultants' idle time will be rather less than 6 mins. during the whole clinic and the patients' average waiting time would be 9 mins. It is pointed out that punctuality is an essential assumption in these calculations. If the consultant is 20 mins. late starting the clinic, there will be six patients waiting instead of two; the patient's average waiting time will then be 27 mins. instead of 9, and the consultant's idle time will be under 1 min. per clinic.

It is suggested that by these means appointment systems can be devised which will keep the patients' waiting time to a reasonably low figure without involving the consultants in long periods of idle time.

Statistics in Administration.

F. A. A. MENZLER (London Transport Executive).

British Transport Review. April, 1952; **2** (1), 34-53.

This paper discusses in general terms a number of statistical techniques useful in routine management as well as research, particularly sampling and experimental design. The importance of proper analysis

VOL.
3
1952

of results to take account of dispersion as well as plain averages is stressed. This is illustrated by reference to fuel pump failures on London Transport central buses, to the incidence of punctures which show a marked seasonal trend, and to the evaluation of trials of heavy duty lubricating oil on engine life.

Operational Research and Action Research.

H. A. C. DOBBS (Foreword by JOHN COLLIER).

Inst. Ethnic Affairs, Washington, D.C., 1947; 21 *pp.*

The author characterises the main features of operational research, "research conducted towards the solution of problems which arise out of the normal course of some administrative action," as

(1) Precise quantitative specification of factors and conditions.
(2) Layman participation in the formulation of problem.
(3) User participation in design of apparatus for solution.
(4) Team technology and integration of specialisms in formulation of solution.
(5) Co-ordination of laymen, specialists and differential techniques by means of trained scientific intelligence using structural insight towards the attainment of a precisely specified overall purpose, such co-ordination being applied not merely at higher levels but at each level where elements of the plan are being worked out.

(Structural insight is the power to see the underlying structure of a problem; the author is of the opinion that such insight is found rather frequently in persons of scientific training.)

Great emphasis is laid on the synthesis both of the various specialised branches of science and technology that may be relevant to the solution of the problem, and also of the scientists', administrators' and users' viewpoints. This synthesis leads to a valuable despecialisation of the specialist.

The development of this relationship between the administrator and the specialist is likely to lead to changes in the traditional structure of the administrative machine. In addition to the traditional arrangements of a hierarchy connected by vertical lines connected only at the top, and the board system on which all members sit as equals, operational research suggests a third way of obtaining communication, by having an extra cross-connecting system outside the usual channels of command. (Readers interested in this topic should refer to Dobbs' *Administrator and Specialist*, in Corona, December, 1949-March, 1950.)

Operational research is compared with "Action Research," which appears to differ in being less quantitative, in involving the administrators in doing the research, and in making less distinction between the research and the action taken. Work in U.S. Indian Administration is quoted as an example.

In his foreword, Collier stresses the need for wholeness in life, and considers the types of research-described aids to creating it.

The Cost of Labour Turnover.

H. J. FURNESS.

The Institute of Cost and Works Accountants, December, 1950; 20 *pp.*

An assessment is given of the extent of labour turnover derived

from Ministry of Labour returns for a period of two years, and an analysis is given of the reasons for workers leaving. About one-third of the turnover is classified as avoidable, the most important reasons being redundancy and dissatisfaction with the jobs.

The factors of cost involved in labour turnover are then reviewed. These are divided into preventive costs under which are included personnel administration, medical services, welfare and pensions; and replacement costs which include inefficiency of new labour, employment department, training, loss of output due to delay in obtaining new labour, tool and machine breakages and accidents due to new labour and costs of scrap and defective work. A detailed case study is given showing how these various items of cost can be determined. The paper is limited to defining the problem and showing how it can be studied and does not make policy recommendations.

Optimality and Degeneracy in Linear Programming.

A. CHARNES (Carnegie Institute of Technology).

Econometrica. April, 1952; **20** (2), 160-170.

This paper deals with two problems: (1) development of a general method for handling degeneracy in linear programming, and (2) construction and rigorous proof of a systematic means of finding all optimal solutions in both the bounded and unbounded cases.

Blending Aviation Gasolines—A Study in Programming Interdependent Activities in an Integrated Oil Company.

A. CHARNES, W. W. COOPER and B. MELLON (Carnegie Institute of Technology).

Econometrica. April, 1952; **20** (2), 125-159.

The techniques of linear programming are here explained in a commercial application—blending aviation gasolines. Blending is critically important to almost all other areas of programming in an integrated oil company. Intelligent programming of production, transportation, manufacturing or marketing generally requires solution of blending problems as an initial or integral part of the whole process, for it is in blending that the final outputs are determined.

In the first part of the paper, questions of optimum programming in a given technological and institutional structure are explored. Computations are executed primarily by means of the simplex technique of Dantzig. Because of the presence of multiple degeneracy and the absence of a general method (at the time these computations were made) of handling such problems, it was not possible to rest securely on the simplex method. Alternative methods of computation were, therefore, explored and bounding techniques were employed to discover possible divergences from optimality. Finally, to test the validity of the results, calculations undertaken by a company programming official were obtained for purposes of check and comparison.

VOL.
3
1952

A relatively simple programme is first calculated and more than one optimal programme obtained. These results are then extended to more complex problems. Finally, the sensitivity of the matrix to possible changes in the coefficients is studied.

The problem of linear programming may be stated as follows: A set of m equations in n unknowns is specified. This may be written in the form $\Sigma_{i=1}^{n} \lambda_i P_i = P_o$

where the P_i and P_o represent column vectors, each with m components. The problem then is to find a set of $\lambda_i \geqslant o$ which satisfies these equations and which maximises a linear functional

$$f(\lambda_i) = \Sigma_{i=1}^{n} \lambda_i c_i$$

The c_i may correspond to any set of relevant criteria but, by the nature of the problem here, they are restricted to prices of outputs or products.

The sensitivity problem revolves around variation in the components of the P_i. The results of these variations may be studied in terms either of consequent variation in physical programme composition (*via* the new activity levels so obtained) or of consequent variation in the value of the functional, or both. Because of the explicit relevance of profits to business activity, attention is here centred on the changes in profit position resulting from such structural variation. Finally, the possible consequences of variation in the vector P_o (which corresponds to levels of expected inputs) and the prices c_i are also discussed. Changes in coefficients of the matrix correspond to changes in the technology. Hence, the effects of programmes of applied research may be examined in terms of the relative profitability of the improvements which the research proposes to effect.

Periodical Literature for Electronic Engineers.

R. C. COILE (Massachusetts Institute of Technology).

Proc. Inst. Radio Engineers. December, 1950; **38** (12), 1380-1384.

Some of the problems of periodical literature for electronic and communications engineers are examined from the reader's point of view. A suggested list of periodicals is given ranked by relative usefulness for keeping abreast of current progress. This ranking is based on the number of references from the periodicals quoted in the annual report of the I.R.E. Annual Review Committee. An examination is also made of references given in papers published in the *Proc. I.R.E.;* this gives a further ranking of periodicals and also provides a distribution of the ages of references found useful.

From this, a method of search for literature on a particular project is discussed. The value of abstracting services is considered with particular reference to their coverage. The possibility of improved methods of documentation which will be useful to the reader as well as the librarian is examined, and its importance is emphasised by the increasing numbers of radio engineers and published papers.

BOOK REVIEW

Operations Research—A Preliminary Annotated Bibliography. JAMES H. BATCHELOR.

Published by Operations Research Section, Engineering Administration Department, Case Institute of Technology, Cleveland 6, Ohio. 95 pp. Obtainable from the Operational Research Quarterly for 7s. 6d. post free.

This booklet contains reference to 309 published books and papers on operational research or closely allied work, each reference being accompanied by a brief note indicating clearly the scope of the work described. Great pains have clearly been taken to make this a comprehensive bibliography by obtaining references over a wide field, even at the cost of including a few references which might be queried on grounds of triviality or irrelevance.

The references are printed in alphabetical order of authors and there are two indexes—one of periodicals and one of institutions. A subject index, or, at least an index of industries, would add to the value of this booklet, which, however, is likely to be useful as it stands, especially to workers exploring the operational research field for the first time.

OPERATIONS RESEARCH SOCIETY OF AMERICA

The first meeting of the Operations Research Society of America was held at Columbia University, New York, on 26th May, as we mentioned briefly in our last issue. These officers were elected:

President: Dr. PHILIP M. MORSE, Massachusetts Institute of Technology.

Vice-President: Dr. ROBERT F. RINEHART, Case Institute of Technology.

Secretary: Mr. JOHN B. LATHROP, Arthur D. Little, Inc.

Treasurer: Dr. ALFRED N. WATSON, Curtis Publishing Co.

The purpose of the society is "to promote the application of operations research, a technique of applying scientific methods to business and military problems."

Seventy-five scientists attended the meeting, drawn from military, university and industrial establishments. Among the subjects of operations research touched upon by speakers were: congestion in air terminals and queueing in cafeterias (Prof. Bernard Koopman); methods of "handling" data from such statistical work as consumer surveys and product life tests (Dr. Russell L. Ackoff); methods to increase company after-tax profits by taking in account corporate income and expense factors affected by changing output (Dr. Alfred N. Watson); the design of trans-continental telephone and television networks (Dr. F. B. Llewellyn).

It is intended that the society shall be incorporated in Washington, and that national and regional meetings shall be held periodically. The next is to be held in Washington in November.

VOL.
3
1952

OPERATIONAL RESEARCH QUARTERLY

World List contraction : *Operat. Res. Quart.*

VOL. 3 NO. 4. **DECEMBER, 1952**

Contents

An Indian View 57
O.R. Club Meetings.. 59
Road Behaviour of Vehicle Drivers—R. J. SMEED 60
O.R. in Electricity 68
Abstracts 69
Media Research Reports 72

AN INDIAN VIEW

This paper was given to the Second Defence Conference, April, 1952, Delhi, India. It is here very much abridged.

A STUDY of the evolution of science, of research techniques and of the extension of scientific techniques to different fields of knowledge, indicate that there are three levels of development, and that they follow a sequence. Each level has a distinct pattern, though all three are interrelated and interdependent. The first stage is when a scientist seeks knowledge of nature. In the attempt he accumulates data on some particular aspect of nature, on the basis of which he establishes certain relationships which form the skeleton of his picture.

He notices in some results the possibility of utilisation for the benefit of mankind, and this he accordingly sets out to effect. This process forms the second level of development.

Having utilised the knowledge (or the discovery) for the benefit of mankind, he goes on to examine the state of utilisation. Has the discovery been properly employed? Can it be improved? Or should it be discarded in favour of something more efficient? These questions imply ethical, economic, psychological, social and technical examinations of the problem, and statistical data become necessary for a correct decision. This is the third stage of the growth of enquiry and forms the third level of research. It is clearly independent of the first two.

At the first level the enquiry is usually specialised and limited to a particular branch of science. At the second level the enquiry is extended by the inclusion of other branches of science. At the third level the enquiry involves a convergence of researches, including those in the so-called Humanites. Further, the researches in the first level may be, and usually are carried out by an individual ; in the second level it may or may not be carried out by the individual ;

while in the third level research can be carried out only by a team of workers.

The research in the first level is commonly known as fundamental, in the second level as applied* while there is no name for the researches in the third level.

Fundamental research is explained as of "academic interest" as opposed to utilitarian, and as being theoretical as opposed to practical. The aim of investigation in this level is to collect new data, to confirm and extend the old, or to establish new relationships between one set of data and the other, and to construct a picture of the shape of things. Consequently, these investigations ought to be carried out unmindful and irrespective of the fact of their being of any use to mankind. But as "there is a most intimate connection and almost an identity between the ways of human power and human knowledge," the researches in the fundamental field are not quite so independent of the motive of utility as is generally believed. Actually the difference between fundamental and applied research is that of the time-lag between the invention and the realisation that it can be utilised. At the end of the 19th century this lag was about 100 years; in other words, fundamental and applied research was well demarcated. During 1930-1939 it was only 30 years, and since the end of World War II the lag has, in some cases, more or less vanished. Thus the old conceptions of fundamental and applied research in their primitive sense are no longer tenable. But although they have lost their earlier significance, they have now acquired new meanings with distinct patterns and characteristics of research activity in each.

The third level of research was not given a name as it was not realised, and is not yet fully realised, as a distinct level of research. Investigations in this direction have been carried out in limited spheres and were given suitable individual names, such as market research, production statistics, etc. What was not realised was the fact that these limited spheres of research formed part of a different level of research. Consequently, the usefulness of the pooling of such specialised research for the advancement of the third level of research could not be appreciated. This realisation dawned upon scientists after World War I, when the various uses of scientific discoveries raised moral and ethical issues. Later it acquired a different and a wider meaning with the depression of the 'thirties, when men started thinking of the misuse of science, saw the unrealised potentialities of scientific discoveries and also started looking for the causes on a general plane.

A second stage of development began when Fighter Command in World War II invited a number of scientists to study air defence

* Practical needs lead to knowledge of things and phenomena which form the basis of any theoretical knowledge; it is also true historically. But after the industrial revolution scientific research was divorced from techniques, leading to a considerable accumulation of theoretical knowledge, which later fed the techniques. We have taken this research relationship as a starting point in arranging the levels of development as it follows as a logical sequence.

VOL.
3
1952

during the battle of Britain, and laid the foundation of the Operational Research Group. It is the contention of this paper that the field of operational research corresponds to researches at the third level. It is carried out by a team of research workers, at a level which is the result of the activities of the first two levels, and where specialised knowledge of various branches is pooled to appraise quantitatively a particular conclusion. It is negative in that it questions well-established practices or a would-be decision and it is positive as it suggests an alternative based on quantitative data. The methods followed in the investigation on this level are the methods of science in general—theoretical, logical, descriptive and statistical. Therefore, in our opinion, operational research should be defined as *that level of research where different uses of a scientific discovery or an invention, its efficiency and degree of utilisation are quantitatively evaluated and the conclusions made to serve as a working basis for socio-technical decisions.*

After having suggested the field, scope and level of operational research and arrived at a working definition, it will be necessary to emphasise once again that it is a level of research and not a branch of science. The results of any one or all specialised branches of science, along with technological knowledge, are utilised by research workers working on problems at an operational research level.

The second point which needs emphasis is that operational research is not experimental. There may be certain points which require experimental clarification, or a series of problems may require experimental work, but all that operational research requires is the data of the experimental work to arrive at a conclusion.

Lastly, the purposiveness and the specific nature of enquiry implicit in operational research work, wherein the aim of proper utilisation is of supreme importance, are stressed.

A. RAHMAN and S. HUSAIN ZAHEER
(Central Laboratories for Scientific & Industrial Research, Hyderabad).

OPERATIONAL RESEARCH CLUB

There will be an open meeting jointly with the Ergonomics Research Society on *Men and Machines in Transport Systems* at 2.30 p.m., February 13, in the Large Lecture Room of the Royal Society DR. O. H. WANSBROUGH-JONES, C.B., O.B.E., will be in the chair.

The discussion will be opened by three papers:

Some Factors Influencing the Road Behaviour of Vehicle Drivers by R. J. SMEED ;

Pedestrian Choice and Judgment by R. L. MOORE ;

A paper from the CAMBRIDGE PSYCHOLOGY LABORATORY on the specific man/machine interaction.

The discussion is expected to include contributions on rail and air problems.

Members may bring guests. Other non-members may apply to the Hon. Secretary for invitations.

SOME FACTORS INFLUENCING THE ROAD BEHAVIOUR OF VEHICLE DRIVERS*

by

R. J. SMEED

ORGANIZED research on the subject of road safety has been going on in this country since 1947. The research, which in the main is carried out at the Road Research Laboratory of the Department of Scientific and Industrial Research, has been concerned with improving the vehicle from the point of view of road safety, with making the roads safer by improvements in surface and design and with improving the behaviour of the road user. It is the last subject, the behaviour of the road user, and in particular the behaviour of drivers, with which this paper is concerned.

One of the ways of reducing the frequency of road accidents is by improving the road behaviour of drivers. At the Road Research Laboratory an attempt has been made to obtain information on some of the factors which influence the road behaviour of vehicle drivers, in order to find out which of these factors are important and which might therefore be used in bringing about the necessary changes in motorists' behaviour. This paper is concerned with the effect on driver behaviour of (i) legal restrictions, (ii) the obvious presence of police, (iii) clearer instructions, (iv) propaganda and (v) a driver's attitude to his task. Some work on other factors influencing driver behaviour has also been done by the Laboratory.

Legal Restrictions

Various legal restrictions are imposed on drivers. There are laws which compel the motorist to observe traffic lights, "halt" signs, speed limits in certain areas or for certain vehicles, laws which regulate the lighting of vehicles and numerous other regulations. It was decided to investigate the reactions of drivers to some of these restrictions. First, with regard to speed limits, measurements were made of the speeds of vehicles on sections of road on which there were no speed restrictions for private cars, but on which speed limits were about to be imposed. These stretches of road all happened to be on the fringes of existing built-up areas. After the speed limit regulations came into force the speeds were again measured, and Table I shows an analysis of the results.

The speed limit regulations had no marked effect on the average speeds; in three cases there was a slight increase of speed and in three cases a slight decrease. In the first five cases, on the average about half the drivers travelled at speeds greater than 30 m.p.h. Although there was no appreciable change in the average speeds there may have been a slight reduction in the proportion of vehicles travelling at very high speeds. There is also some indication that the

* This paper was given to the meeting of the British Association for the Advancement of Science, Section J, Psychology; Belfast, September, 1952.

VOL.
3
1952

speed limitations reduced the number of accidents which involved personal injury, but further work on this is necessary before a final conclusion can be drawn. There is also evidence that the introduction of a speed limit in built-up areas in 1935 did have a marked effect on accident frequency.

TABLE I

Site	Average Speed Before (m.p.h.)	Average Speed After (m.p.h.)	Change in Speed (m.p.h.)
1	30.1	31.2	+1.1
2	29.4	28.5	−0.9
3	30.0	31.3	+1.3
4	31.4	30.3	−1.1
5	29.7	30.6	+0.9
6 (10 m.p.h. lmt.)	26.3	24.9	−1.4

The fact that the speed limits have no marked effect on speeds, but that they may tend to reduce accident frequency, are not necessarily incompatible, especially as the speed limit may have affected the highest speeds.

All these cases of the imposition of speed limits were on the outskirts of towns. The only obvious change that was made was to move a speed limit sign along the road. It does not follow from these results that speed limits in general have no effect on speeds of vehicles, but it does seem to follow that the mere imposition of a speed limit without any special steps of enforcement and without attempting to bring the speed limit to the notice of the motorist other than by a pair of signs, which he may not see, does not always have a marked effect on speeds.

Again, measurements were made of the speeds of commercial vehicles on some roads which had a speed limit; the heavy goods vehicles are by law restricted to 20 m.p.h. and the light goods vehicles to 30 m.p.h. It was found that almost 60 per cent. of light goods vehicles and more than 90 per cent. of heavy goods vehicles travelled at speeds greater than their legal limits. Table II shows the results.

In each case the majority of the vehicles were travelling faster than they should have been, and in many cases very much faster. Clearly on most roads which have a general speed limit, speeds in excess of 30 m.p.h. are not possible during many hours because of the traffic congestion, that these results do not apply to congested town streets.

These results form an interesting comparison with those of American investigators. A paper by Price (1) of the Institution of Transportation in Berkeley, California, states "the data collected indicated that neither the 'Speed Zone Ahead' sign nor the numericals painted on the pavement had any effect on the traffic." A study by the Maryland, U.S.A., State Road Commission (2) concluded that drivers did not observe posted speed limits, even when there was

1 PRICE, H. O. *Highway Res. Abstr. Sept.*, 1951; **21** (8); 12.
2 Maryland State Road Commission. July, 1951. *Highway Res. Abstr. Sept.*, 1951; **21** (8); 15.

advance warning of the speed limit zone.

TABLE II

Speed	Vehicles with speed limit of : 20 m.p.h.	30 m.p.h.
Greater than 20 m.p.h. ...	94%	99%
Greater than 30 m.p.h. ...	38%	58%
Greater than 40 m.p.h. ...	2%	5%

There are thus four separate sets of data on the effects of speed limits, two from the U.S.A. and two from this country, all of which show that under some circumstances a large proportion of motorists break speed limit laws.

Some work has been done on the reactions of drivers to "Halt" and "Slow" signs. Junctions of minor and major roads were selected which appeared to be similar with respect to layout, traffic, etc., and counts were made of the numbers of vehicles on the minor road which stopped before entering the major road. On some of the minor roads there were "Halt" signs, some had the sign "Slow—Major Road Ahead," and some had no sign. Results are given in Table III.

TABLE III

	Percentages of drivers who stopped at junction after passing : "Halt" signs	"Slow" signs	No sign
Built-up areas			
No vehicle on major road ahead	69	32	8
Vehicle on major road ahead ...	83	57	42
Non-built-up areas			
No vehicle on major road ahead	36	11	—
Vehicle on major road ahead ...	81	47	75

It was found that in built-up areas on some minor roads leading to a junction with a major road, 69 per cent. of the vehicles stopped when there was a "Halt" sign, 32 per cent. stopped when there was the sign "Slow—Major Road Ahead," and only 8 per cent. when there was no sign All the differences are statistically significant. These figures were for the occasions when it was not obvious to the driver that there were vehicles on the major road ahead. If, however, a vehicle passed along the major road during the time the minor road vehicle traversed the last 50 yards before reaching the junction, the figures increased to 83 per cent., 57 per cent. and 42 per cent. respectively. Again all the differences are statistically significant, and also each of these proportions is significantly greater than the corresponding figures for the cases when there was no evidence of traffic on the major road ahead.

In non-built-up areas, that is on country roads, most of the trends are in the same direction, but the differences are not all significant.* Only 36 per cent. actually stopped after passing a

* Significant ones are the following for N.B.U. areas :—

No vehicle ahead	Halt>No.	Halt>Slow.
Vehicle ahead	No>Slow.	Halt>Slow.

VOL.
3
1952

"Halt" sign if there was no evidence of traffic on the major road ahead.

It appears, therefore, that "Halt" signs are by no means universally respected, although a considerable proportion of motorists do observe them properly. However, many drivers do realize the necessity for stopping, owing to the presence of other traffic. Since "Halt" and "Slow" signs are normally erected where they are considered to be most necessary, traffic is in any case more likely to stop at the junctions following these signs than at other junctions. A study of the relative behaviour before and after the signs are erected is necessary in order to get a conclusive result, and such a study is planned. But this investigation does show the proportion of people who do not obey the law.

Another aspect of the driver's attitude to legal restrictions is given by his reactions to traffic lights. These reactions are very different in the heart of London from what they are on a road with no speed limit on the outskirts of London. In the first case, of vehicles stationary in the front rank of queues at traffic lights about quarter crossed the stop-line on the red-with-amber, which is against the law. On the road in the outskirts about half did so. But in the second case there were few pedestrians, there was little cross traffic so that the intersection was often empty before the end of the red phase; the traffic was faster, there was usually good visibility of the crossroads and the stop-line was well set back from the intersection. Hence as regards this regulation, also, drivers appear to vary their degree of compliance with the law in accordance with the traffic and safety conditions prevailing.

We have thus investigated the motorists' reaction to legal restrictions in three cases:—

(1) With respect to speed limit.
(2) With respect to "Halt" signs.
(3) With respect to traffic lights.

In all three cases it appears that if traffic conditions permit, large proportions of drivers do not automatically obey these restrictions fully, although it is possible that in all cases they pay some respect to them. Further investigations are required to find what proportion of motorists are affected and by how much in each case.

The Obvious Presence of the Police

The second subject of this paper is the effect of police activity on driver behaviour. It was found, first of all, that the effect of police motor patrols on accidents was very well marked. Before the last war the Home Office started an experimental motor patrol scheme. In seven police forces the existing police were augmented by specially trained police who patrolled the roads giving advice and warning to motorists, cyclists and pedestrians, and who set an example by their own behaviour.

The main idea was co-operation and education rather than prose-

cution. Owing to the war the scheme was abandoned. The scheme had a marked effect on the accident position, and Table IV shows the results of an analysis.

TABLE IV

	Forces Operating Motor Patrol Scheme	Forces Not Operating Motor Patrol Scheme	Difference
Fatalities			
In County Areas	6.0% Decrease	4.3% Increase	10.3%
In Town Areas...	7.0% Decrease	1.3% Increase	8.3%
Other Casualties			
In County Areas	15.2% Decrease	3.0% Increase	18.2%
In Town Areas...	0.7% Decrease	3.1% Increase	3.8%

The comparisons are between those forces operating and those not operating the scheme for the years 1937 and 1938. The scheme began in most places in April, 1938. For the county forces operating the scheme there was a decrease of 6 per cent. in fatalities, but in the other county forces there was an increase of 4.3 per cent. Hence this Home Office experimental motor patrol scheme was associated with a decrease of 10.3 per cent. of fatalities in county areas, and similarly a decrease of 8.3 per cent. of fatalities in town areas. These data refer to the whole of 1937 and 1938, monthly figures not being available. If we make allowance for the fact that the scheme did not start in most places until April, 1938, it appears likely that it caused a decrease of about 12 per cent. in road fatalities.

As there is such good evidence of the effectiveness of police patrols in reducing accidents, an attempt has been made recently to find changes in drivers' behaviour which would account for the accident reduction. One might suppose that a police patrol on a road would make everyone take greater care; for example, drivers would go rather more slowly. An experiment was therefore carried out on a de-restricted road to find the effect on speed of frequent police patrols. A police car and a police motor-cycle traversed a five-mile stretch of a wide de-restricted road, a police patrol passing the observation point every 10 minutes. Traffic flow was quite free, the maximum speed recorded being 83 m.p.h. The experiment took four days. On the first day no police were present, on the second and third days police were present in the morning, and on the fourth day again no police were present. A statistically significant reduction in speeds was found between the first morning and the second and third mornings. The speeds of commercial and public service vehicles were chiefly affected. The proportion of them travelling at more than 40 m.p.h. was reduced from 21 per cent. on the first morning to 12 per cent. on the second and third mornings. There was, of course, no speed limit for private cars, but even for these vehicles, it was found that the presence of a police patrol was associated with a reduction from 44 per cent. to 37 per cent. in the proportion of vehicles travelling at more than 40 m.p.h.

In another experiment the effect on drivers of a uniformed policeman, who was inactive, standing on the pavement near a pedestrian

VOL.
3
1952

crossing for periods of quarter of an hour on and off, was measured. (This experiment took place before the large-scale introduction of zebra crossings with its attendant publicity.) It was found that 25 per cent. more drivers gave precedence to pedestrians when the policeman was there, than when he was not there. The policeman took no part in the control of traffic and yet this result was found.

Three separate investigations have thus shown that the presence of the police has a marked effect on the behaviour of drivers.

Clear Instructions

Some of the apparent lack of co-operation by drivers referred to earlier might plausibly be ascribed to lack of clear instruction. There is evidence of this from our work on pedestrian crossings. An investigation was made into the effect of striping crossings with zebra markings, when they were in the experimental stage in 1948, by comparing the proportion of drivers who gave way to pedestrians on these crossings before and after they were striped, using as controls some plain crossings in the vicinity of the striped ones. Fig. 1 shows the results

The stopping index used in these figures is defined as the percentage of total drivers who gave way to pedestrians wishing to cross. In this experiment the number of vehicles passing every 15 minutes was compared with the number of drivers who gave way to the pedestrians. In the case of a line of vehicles only the front one was counted as giving way. The majority of vehicles had either no need to stop, for there were no pedestrians trying to cross the road, or they were not in the front line of those held up, so that the stopping index is necessarily small. But it will be seen that the proportion of drivers who stopped went up after the crossings were striped, although at a control crossing near by with no striping, there was no change. When drivers could clearly see the crossings (that is, when the crossings were striped) they were much more likely to give precedence to pedestrians than when they approached the plain crossings which were not so visible.

Similarly, the lighting of crossings at night, either by floodlights or by lighted beacons, was followed by a marked improvement in driver behaviour as regards giving precedence to pedestrians. This experiment has been repeated a large number of times with the same result, and there is overwhelming evidence that making pedestrian crossings more visible causes a marked improvement in motorists' behaviour at them.

Propaganda

We know very little yet about the effect of propaganda on motorists' behaviour. The only evidence we have so far is that their behaviour (as measured by giving precedence to pedestrians at crossings) improved after the nation-wide Pedestrian Crossing Week in April, 1949. But the improvement was only temporary, apparently lasting but a few months. It is also likely that the improvement was partly due to extra police activity. An experiment designed to

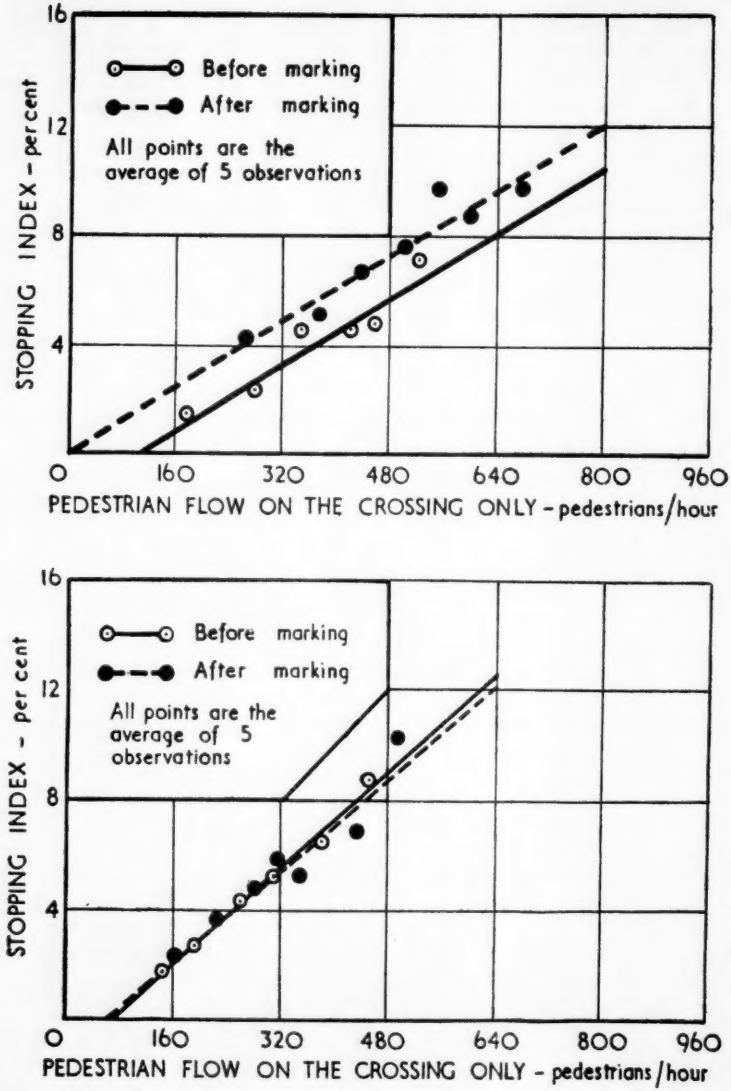

FIG. 1.—*Stopping Index v. Pedestrian Flow before and after marking the experimental crossing.*
Above: Experimental crossing.
Below: Control crossing.

VOL.
3
1952

give a reliable measure of the effect of propaganda will be difficult and expensive, but we hope to carry it out in due course.

A Driver's Attitude to his Task

Evidence is available showing that a driver's behaviour is sometimes determined more by what he thinks is happening than by what is actually happening. For example, at night when a driver with dipped headlamps meets a vehicle with headlamps not dipped, he frequently switches his own headlights on full to show that he is being dazzled. Originally the effect of dipping was to put out the offside lamp. But on most new cars the offside lamp is not put out —its aim is deflected towards the kerb and the intensities of both lamps are decreased. It has been found, however, that the glare from a single lamp is tolerated to a much greater extent than the same amount of glare from a pair of lamps. A single lamp whose glare intensity at 250 ft. was 2½ times that of a correctly aimed double dipping system provoked the same reaction as the double dippers. Hence prejudice or imagination seems to play some part in the dazzle problem.

Similarly, the speeds of vehicles on wet roads have been found to be slower than those on the same roads when dry if the road looks slippery when it is wet, but not so if it does not look slippery ; in that case the average wet road speed was about the same as the dry road speed, even if the road was actually slippery.

I have in this paper so far dealt entirely with factors operating on drivers in the mass. But individual factors are of extreme importance, and this is well illustrated by measurements of the speeds of vehicles. It was found that about 10 per cent. of 8 h.p. cars travel faster than the average high h.p. sports car. This does appear to show the importance of the individual factors.

Conclusions

To sum up—there is evidence that some legal restrictions are not observed at all well by drivers. Drivers appear to vary their degree of compliance with the law in accordance with the safety and traffic conditions prevailing. The obvious presence of the police, however, has a marked effect on the behaviour of drivers and on the accident position. A driver observes pedestrian crossings better when the crossings are made more visible by striping and lighting them, thereby showing that he behaves more courteously when it is made easier for him to do so. His behaviour, too, is determined more by what he believes is happening than by what is actually happening.

Clearly there is a vast amount of work to be done on other factors which may be of great importance in affecting the road behaviour of drivers. The physical environment of the driver, including the design of the vehicle, many physiological factors of the individual driver, such as his vision and physical deformities, numerous aspects of the attitude of the driver, all these subjects have not yet been adequately investigated and may be of great importance in reducing accidents on the road.

O.R. IN THE ELECTRICITY SUPPLY INDUSTRY

This note is abstracted from a paper by P. SCHILLER *in Proc. Inst. Elec. Engrs.*, 1951 ; **98** (1), 229-238.

BECAUSE of the almost direct proportionality between the maximum demand on a generating system and its capital cost, it is a persistent problem to enhance the "load factor," the ratio of average to maximum demand. An important field, therefore, may be called *load research*. This is the ascertainment of the load characteristics of each of the principal classes of consumer ; the different types of load ; and the various alternative types of apparatus and methods available to perform a given service. The first is of interest chiefly in allocating costs ; the second and third are of importance in enabling desirable loads, appliances and methods to be encouraged by sales propaganda, tariff measures, etc., and those that appear undesirable to be discouraged.

Another field is *consumer research*, directed to ascertaining development trends, and to planning selective load-building.

Under the same heading fall researches into the use made of specific appliances by individual consumers and their collective response to different types of tariff, tariff charges, different forms of accounts collection, etc.

In addition to load and consumer research, there are various limited problems that have been made the subject of operational research, such as the quantitative assessment of the incidence of voltage variations at consumers' terminals and of the related economic aspects, with particular reference to the loss of revenue entailed by reduced supply voltage.

TECHNIQUES

Colective Measurement of Loads. The electricity supply industry can measure the collective demand made by its customers at any moment at the principal sources of supply and at any distribution centre, down to the service intake of a small block of flats. In certain circumstances (e.g., when of two comparable groups of consumers one has gas and one electric cookers) the effect of a particular factor can be simply deduced.

An analogous procedure can be adopted in attempting to analyse the load on comprehensive systems by consumer classes.

There are also some technical means of segregating the effects of particular appliances for groups of premises.

Sampling. When there are large quantities of reasonably homogeneous consumers or data to be investigated, sampling in accordance with statistical theory can be employed, both from records and by survey. The first thorough application of this appears to have been in New York in 1939-40, when a sample was completely surveyed, and recording demand indicators were used to obtain individual load records. A large scale sampling survey of domestic consumers was

VOL.
3
1952

made in the U.K. in 1946, and selecting samples for the installation of test instruments has since become a standard routine.

A possible future method is the division of new housing estates or towns into homogeneous sections of several hundred dwellings, each section being equipped with a different combination of appliances.

Consumption Analysis. Only the total electricity consumptions of individual consumers are usually available. An interesting statistical method is used, by which for each consumer there can be formed an equation of which one side consists of a sum of unknown variables, each of them representing the annual consumption of one of his appliances, whilst the sum total is given by his known annual consumption. These equations are treated collectively by one of the methods of solving simultaneous equations. Specific appliances or services can be sub-classified, e.g., electric space-heating according to the number of kilowatts of installed capacity, or cookers according to association with a kettle, sink-fitted water heater, etc. From this can be deduced the contribution of a particular appliance to the average total consumption per consumer of the group concerned, and the method can also be used to discover and keep under review the trend of development of the principal components of consumption.

ABSTRACTS

New Mathematical Methods in Operational Research.

BERNARD O. KOOPMAN (Columbia University, U.S.A.).

J. Operat. Res. Soc. of Am., Nov., 1952; **1** (1), 3-9.

When first looking at practical O.R. problems, both the O.R. workers and mathematicians often think that only elementary mathematics are needed, but later find that the problems require powerful methods sometimes going beyond existing knowledge. Examples are given to illustrate how this may happen in problems involving the calculus of variations where the maximum required occurs not inside the region delimited by the constraints but on the boundary ; other complications may arise in such problems due to the manner in which the quantity to be maximized depends on the quantities under control, or again where the solution required is a minimax instead of a maximum.

Some treatments of stockastic processes are discussed ; a thermal analogue is described and an analytical solution given to verify one of the criteria set up.

Some New Statistical Techniques Applicable to Operations Research.

RUSSELL L. ACKOFF (Case Institute of Technology).

J. Operat. Res. Soc. of Am., Nov., 1952 ; **1** (1), 10-17.

Three methods are described which the author has found of particular interest and usefulness. The first concerns statistical tests applicable to maintenance and replacement problems where the life-span and fatigue-point data have an underlying distribution which

is exponential in character. The second is a technique which may be applied in social and market surveys involving house-to-house personal interviews; one of the greatest problems in surveys of this type is the large percentage of the sample of people to be interviewed that is not available, and a method is suggested by which the not-at-homes may be included in the sample without a costly call-back procedure.

Finally, short-cut procedures, commonly known as inefficient tests, are discussed, with particular reference to the use of Binomial Probability Paper.

Applying Research to Steel Works Plant and Operation.

R. F. JENNINGS (British Iron and Steel Research Association).

The Engineer, 18*th July,* 1952; **194** (5034), 83.

Very large sums of money are spent on large scale research for the development of industrial processes, but is this money used in the most effective way? And are our research efforts as a whole correctly balanced in relation to the needs of industry? The author suggests that not enough research effort is devoted to the design of steel works plant as compared with that expended upon the development of processes, and he gives examples of items of plant, the design of which might be improved through the application of operational research.

A Forecast of Effects of Economies in London Telephone Directory Services.

D. L. LAMBERTH (The Social Survey). 28 *pp.*

Two surveys were made at the request of the G.P.O. to find the period for which the London directory could be withheld without causing inconvenience to subscribers or increasing the cost of the Directory Enquiry Service to such an extent as to offset the saving in directory costs. The effect of dividing the London directory into six sections was also considered.

Data was obtained from two sources. (1) Records of outgoing telephone calls kept by subscribers for a fortnight. From an analysis of these factual data (particularly of the difficulties encountered which might have been due to wrong entries or no entries in the directories) it was possible to predict the maximum effect on the Directory Enquiries Service of reduction in the number of issues of the directory. (2) Interviews with subscribers, the subscribers being prepared beforehand so that they were able to give considered opinions. Analysis of these opinions showed that they were consistent with the factual data under (1). This was important to ensure that economies made in accordance with the factual data would not lead to ill-feeling among subscribers.

The data collected are given in detail and the conclusions which may be drawn from them are indicated.

VOL.
3
1952

Technical Objectives in Pre-Planning Production.

K. E. HARRIS (Sir Robert Watson-Watt & Partners Ltd.).

British Kinematography, Jan., 1951 ; **18** (1), 18-29.

The object of pre-planning is defined as to arrange for a film to be produced in the smoothest possible manner with the greatest economy, consistent with an adequate scope for artistic expression.

Three distinct problems are considered. First, planning the division of the film into slates ; an analysis of the production records of completed films shows clearly that an increase in the length of slates offers a possibility of considerable saving in the time spent with the film on the floor. Second, the restriction of the number of takes of each slate ; an analysis is made which suggests there is little prospect of great saving by this method. Thirdly, an analysis is made of retakes and their causes, and consideration is given to the use of devices which may reduce the number of retakes which are made.

The Strategy of Science.

(Memorial Lecture to Society of Chemical Industry, 9th July, 1952.) HENRY TIZARD.

Chemistry and Industry, 16th Aug., 1952 ; 788-792.

The military commander never has at his disposal all the reserves that he would like ; by strategy he makes the best use of what he has. So in the application of scientific resources of manpower and capital expenditure, good strategy is essential if the best use is to be made of them. Such strategic forethought is necessary at the national level and within each industry, and the argument is developed with particular reference to the U.K. economy as a whole and to the competitive position of the chemical industry in world markets.

Engineering and Statistics at the Pacific Front in World War II.

ROGER I. WILKINSON (former Operations Analyst with the 13th and Far East Air Forces).

The part played by operations analysts in solving the " front line " problems of the Army Air Forces in World War II is described briefly. The kinds of problems presented and the talents required in men able to solve them are discussed. Examples are given of a number of projects undertaken in the course of two years by the radar specialist with the Operations Analysis Section at the Thirteenth Air Force located in the south and south-west Pacific. Something of the meagreness of the data commonly available, the urgency for obtaining a reasonably reliable answer quickly, the variety of techniques involved in handling data, and the form in which recommendations may be acceptably presented, are indicated.

MEDIA RESEARCH REPORTS

A Critical Notice

The Hulton Readership Survey, 1952. *Hulton Press.*

Focus on Illustrated. *Odhams Press.*

Millions for Advertisers

(i) Biscuits ; (ii) Cereals ; (iii) Jam and Marmalade. *Odhams Press.*

The Audience for Screen Advertising. *Theatre Publicity Ltd.*

MANY readers may feel that these publications do not relate to operational research. Marketing and media research as such are doubtless not the general or usual function of operational research workers. But the operational research unit which ignored all statistical data from sample inquiries of this kind would soon be out of business. Sample survey data form today a useful and substantial proportion of source material. It is as source material that operational research workers and others need to take note of this kind of information.

Operational research workers should know even the unfamiliar sources of data. The first-named publication is no longer in this category. In its present form, or substantially so, the **Hulton Readership Survey** has been published for the last six years as a fairly regular annual. The delay in the publication of the 1952 issue has special significance, to which reference will be made later. As its name implies, the Survey is designed to give data relating to the " readership " of the main periodicals and newspapers. It covers, in fact, just over 60 such publications.

Before the publication of readership surveys it was known in an impressionistic sort of way that circulation and readership were not the same thing, but data only in respect of the former were available. It was known, for example, that the *Radio Times* would have a life of at least a week, whilst the life of an evening paper would normally be a few hours, and a major daily seldom more than one day. Every member of the household would be likely to refer to the *Radio Times* for some purpose or other during the course of the week. Whether such reference constitutes " reading " is perhaps debatable, but figures relating to a somewhat hazy concept of " readership " are, for some purposes, preferable to circulation. Both sets of information are better than either singly. Circulation data are poor information in deciding media for advertisement, mainly because they tell nothing about the types of persons who are included. In general an advertiser seeks to reach an audience about which he can make certain statements—his product might not interest those earning below a certain weekly sum, or above a certain age. He does not want to spend

VOL.
3
1952

money in telling people who are not likely to be interested about his product, or, at least he wishes to reduce the number of units of information for which he pays but for which he believes he will not be likely to get any return.

Again, before readership surveys were available, impressions were a concomitant of experience. Laymen would know that the *Times* was doubtless a good medium if the goods advertised were of appeal to the upper income levels, and advertising experts could carry this sort of feeling much further. But they could not put any definite number on it. The **Hulton Readership Survey** enables numbers to be put to such concepts. Special classes of advertiser are helped by special tabulations. We are told the readership habits of men and women, house owners, car owners, cycle owners, smokers, and "beauty conscious" women. Regional analyses, social class analyses, family type analyses, and so on, provide much information of value to the advertiser who uses it wisely.

The Survey is not, of course, the answer to all problems of media, nor does it give any information regarding the rates charged for space. It is claimed that this project is completely independent of any interest in the matters reported. Although it bears the name of well-known magazine publishers, there is no doubt that this claim is true. The field work is undertaken by an organisation in no way associated with the magazine publishing interests, and is supervised by a panel of experts who represent both the consumer of the research and other research interests.

Before we look at the technical problems which are common to all the publications listed, it is desirable to point out the differences. **Focus on Illustrated** is of particular interest, since the Hulton Readership Survey includes the magazine *Illustrated*, to which this publication relates, and cross-checks are available. All of the Odhams publications are products of the market research department of Odhams for the Advertising Director. They cannot claim independence. A thorough check of the data given in the **Focus on Illustrated** against the Readership Survey reveals, however, that the facts have been presented in an unbiased and quite objective manner. Information regarding circulation and the cost of advertising in that paper are also given, together with other analyses not found in the general Readership Survey. There are slight differences between some of the Readership Survey's figures and the "Focus" booklet data, but random sampling was not used and no theoretical errors can be calculated. No differences are large enough to result in one line of action if one set were taken as correct, and a different line of action if the other were. The largest difference noted was in the estimate of the readers of *Illustrated* in Scotland, with the Readership Survey giving an estimate of 490,000 and the Odhams' report an estimate of 700,000. Total readership is estimated by the former at 5.8 million and by the latter at 6.3 million.

The remaining productions of the Odhams Press turn their attention to various product groups, and present readership and circulation data of special interest to manufacturers of these groups. It is estimated that *Daily Herald* readers spend £9.5 m. on jam and marmalade in a year, £10.1 m. on biscuits, and £5.4 m. on breakfast cereals and porridge oats. They give brand distributions for readers of the Herald and other data which, whilst obviously intended to attract advertisers to the medium of the Herald, are well and objectively presented. If similar publications were available for other papers and journals the effectiveness of British advertising should be increased very considerably.

The last-named publication, **The Audience for Screen Advertising,** has a similar intention to the publications of the Odhams Press, except, of course, that it attempts to sell screen advertising and not newspaper or magazine media. It is not the objective of this publication, nor those of Odhams, to present the data which interest them in comparison with other data relating to competing media. The degree of detachment obtained by Odhams is, with this in mind, quite remarkable.

The Audience for Screen Advertising seems fairly describable as a "self-conscious" document. A few examples will make clear what is meant by this. In the early pages it states that the idea that the screen audience is a "bunch of adolescents" is proved wrong, and a claim is made that the cinemagoers "are discovered as representative of the whole population." Later in the text we learn that 87 per cent. of the 16-24 year-olds visit the cinema each week, against 24 per cent. of the 45 and over age group. This is certainly not proportional representation. A chapter is headed "Adults Visiting Cinema," and figures and tabulations are given. Only by careful reading of the text is it discovered that by adult is meant persons of 16 years of age and over—a definition which the publishers are fully entitled to make, but one which differs from most others. Tabulations are not fully headed, nor would they otherwise get full marks in a statistical examination. Weekly cinema-going by age group is tabled as follows:—

16-24	4,600,000
25-34	3,800,000
35-44	3,000,000
45 and over	4,120,000

It is learned elsewhere that only the civil population are included. The first age group, 16-24 years, appears to cover nine years, and the second and third 10. It is only when readers remember what they noted on other pages that they realise that this age range is more nearly eight years. For nearly half the sample two years will be removed. The males on National Service will almost all be in this age group. The ratio of attendance by age groups, viz., 87 per cent. and 24 per cent., give a picture of a highly-skewed distribution, whilst with the same facts a comparatively square table is derived.

VOL.
3
1952

The facts are the same, but since population totals and other material relevant to the full interpretation are not given in this table, the impression is different. The impression which is given most space is the one which we are desired to have. In reading any publication which is advertising a product, one must expect the best possible interpretation to be given to the facts, and this is perhaps particularly so when the advertisement is advertising advertising media (!).

All these studies are, however, to be welcomed as providing data where none existed before. They should help the purchaser of advertising to know what he is buying.

The technically skilled should remember that these documents are not designed for the use of research workers. Operational research workers will be very disappointed in the methods and the presentation even at its best. They will want to ask many questions to which they will not find answers. They may look to see how the presentation lines up with the recommended standards laid down, for example, by the Statistical Office of the United Nations in *Preparation of Sampling Survey Reports*, and will find more ignored than complied with. The most notable omission is the copy of the interviewing schedule. The replies to questions do not state what words were used to obtain the information. It would cost so little to add this information and might protect the producers from ill-informed comment. According to Hulton's, for example, *Illustrated* can claim amongst its readers 2,020,000 gardeners, Odhams claim 1,370,000 whose hobby is gardening. The wording which was apparently used explains the difference—some do gardening because they like it, others because they have to. When we compare comparable wordings and refer to " working regularly in garden " (whether liked or not), Odhams get 2,010,000 and Hultons 2,020,000 as their respective independent estimates. Both wording and often positioning of questions is important in interpretation, yet the marketing surveys which give these essential data are very few.

Further work on the figures is often hampered or made quite impossible because percentages are given. When this applies to two dimensional tabulations no tests of association can, of course, be made, since the individual cell frequencies cannot be estimated. It has become an unwritten but immutable law that all marketing research data shall be presented with utmost simplicity. Simplicity reigns even at the expense of accuracy, on occasion ; and, quite often, of utility

Marketing and media research places its faith almost exclusively in " quota " sampling, for which errors cannot be calculated. In those cases where there is evidence, the results have not usually been far out. It is clear, however, that the **Hulton Readership Survey** had their faith shaken when the first results of their most recent study came in. They say that tabulations " showed readership trends of considerable significance." They therefore decided to obtain the check afforded by a sample on a " probability " basis. They assure

us that the results of the two samples were within statistical margins of error. A search was made to identify the factors which induced this rather drastic action. Comparing their preceding survey figures with the current reveals that *Lilliput* had in the intervening time (if both sets of figures were correct) lost nearly half its readership, *Picture Post* over a third, *Punch* a quarter, and the *Evening Standard* just over a sixth. How they can assure us that the double sample is evidence of the "trends" is unclear. There was no similar proof of the earlier figures, and the fixing of one point in time does not justify the term "trend."

We are not told whether the body who carried out the probability sample had had much experience of this sort of sampling, the number of stages are not quoted, we are not told the non-contact rate, or the refusal rate. We do not know whether checks were made on a sub-sample to test whether the interviewers carried out their sampling instructions accurately, and we do not know what these instructions were. There is no way of judging the efficiency of a quota sample—that is inherent in its type—but the whole reason for probability sampling is in that it can be checked ; failures to interview pre-selected informants are known, the difficulty of making contact is objectively ascertainable, and so on. We may be being asked to compare a bad probability sample with a good quota sample. In view of the interest in the problem of cheap methods of population sampling, it is hoped that the full details will eventually be released. If the availability of informants is an important feature in quota sampling, as in random sampling, then especial interest would devolve on the comparison of the results of the two methods relating to cinema-going and age group, and particularly to the upper age groupings.

Research workers may feel justified in rejecting the whole field of statistical data provided by the sources illustrated by this note until there is sufficient information provided for them to know exactly what has been done and what exactly was the unadjusted result. If, however, they have to make practical decisions relating to media, they will be grateful for the information which these sources provide, and they will exercise great care in its use. They may feel that the presentation of data by those who have special interests in the facts they provide is not in the best interests of science. They may, in this field, even have to carry out considerable research to find out what the interest relationships are. But there are few cases where science can not only be detached, but also appear to be detached from any interest in the results of its work. In America, much research of the kind described is carried out by the Foundation for Advertising Research, which is an independent research body sponsored by a large variety of advertising interests, and there are economic as well as possibly other advantages and disadvantages in this method.

On balance, it is probably true to say that this sort of information is useful, and could be more so. A.B.H.

VOL.
3
1952